I s o l a t i o n
Technologie Services
ITS
acoustique

Report
PhR15-008A

User's manual for the software SILDIS (*)

** Sound Impact Limitation: Design for Industrialized Solutions*

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Abstract:

The **prediction of performances of products and construction systems for noise control engineering** often requires an approach whose nature is computationally intensive, making its application difficult for most acoustics practitioners. The software SILDIS has been developed in order to make possible such a prediction **without any computational effort from users, by the means of a single PC-tool appropriate for a wide range of industrial engineering purposes.**

Regarding the multi-disciplinary scientific and technical background, suitable approaches of all times, able to be included in the general layout of the program, have been selected and encapsulated in a easy-to-use Excel based software using drop-down menus and providing results in tabular and graphical form (French or English language) with comprehensive input/output data on a unique printable simulation report.

Almost **all acoustics calculations are performed at single frequencies and displayed per 1/3 and/or 1/1 octave band: global values with respect to a chosen reference spectrum are computed** whenever it makes sense.

MODULE 1 **prediction of acoustic and aerodynamic performance of silencers:**

- **either dissipative silencers** (for those equipments **the considered cross section can be either rectangular or round, with or without a central pod, with or without an intermediate annular splitter**) **for a lining including up to 4 porous media, up to 4 series cloths, up to 4 series perforated protections selected among a library including for each kind of layer more than 20 referenced materials.**

- **or resonant silencers with so called Pine Tree splitters** (for those equipments **the considered cross section can be rectangular**) **for a lining including up to 4 porous media, up to 4 series cloths, up to 4 series perforated protections selected among a library including for each kind of layer more than 20 referenced materials**

For a rectangular silencer the results of the calculations are comparable with the standardized measurement: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units- Insertion loss, flow noise and total pressure loss.

MODULE 1A **prediction of acoustic and aerodynamic performance of silencers with discontinued splitters:**

- **dissipative silencers** (**considered cross section being rectangular) for a lining including 1 porous medium, 1 series cloth, 1 series perforated protection (material properties registered in database)**

For a rectangular silencer the results of the calculations are comparable with the standardized measurement: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units- Insertion loss, flow noise and total pressure loss.

MODULE 2 **prediction of acoustic performance of plane partitions for an acoustic structure including up to 2 porous media, up to 2 series cloths, up to 2 series perforated protections, up to 2 sets of identical series thin plates with up to 1 complementary rear set of identical series thin plates selected among a library including for each kind of layer more than 20 referenced materials (with an atmospheric back or with an impervious rigid back).**

The results of the calculations are comparable with the standardized measurement: (in case of an atmospheric back) see NF EN ISO 10140-2 Acoustics – Laboratory measurement of sound insulation of building elements. Measurement of airborne sound insulation and (in case of rigid impervious back) see NF EN ISO 354 Acoustics – Measurement of sound absorption in a reverberation room and also ISO 10534-1 Acoustics – Determination of sound absorption coefficient and impedance in impedance tubes – Part 1: Method using standing wave ratio.

MODULE 3 **prediction of acoustic performance of duct walls: either with a rectangular cross section, or with a circular cross section (including folded spiral seam ducts).**

The obtained results are not comparable with standardized measurement due to the lack of documents formalizing corresponding measurement procedures.

MODULE 4 prediction of acoustic performance of straight ducts either with a rectangular cross section, or with a circular cross section (including folded spiral seam ducts).

The obtained results are not comparable with standardized measurement due to the lack of documents formalizing corresponding measurement procedures.

MODULE 5 prediction of break-out noise: either of straight ducts (with a rectangular cross section, or with a circular cross section - including folded spiral seam ducts) or of silencers.

The obtained results are not comparable with standardized measurement due to the lack of documents formalizing corresponding measurement procedures.

MODULE 6 prediction of acoustic performance of bends: with a rectangular cross section, or with a circular cross section, or with mixed cross sections).

The obtained results are not comparable with standardized measurement due to the lack of documents formalizing corresponding measurement procedures.

MODULE 7 prediction of nozzle reflection: with a rectangular cross section or with a circular cross section.

The obtained results are not comparable with standardized measurement due to the lack of documents formalizing corresponding measurement procedures.

MODULE 8 prediction of the sound impact of duct systems including components such as silencers (dissipative or resonant), straight ducts sections, bends with a rectangular cross section, or with a circular cross section, or with mixed cross sections (for some components)

MODULE 9 modelling of sound decay in enclosed spaces

The obtained results are comparable with standardized measurement: cf. NF EN ISO 3382-2 Acoustics - Measurement of room acoustics parameters- Part 2: reverberation time in ordinary rooms.

In this user’s manual, a presentation of this calculation program is made, for the people concerned (at ITS or elsewhere) by the design of soundproofing equipment related to applications in the field of industry, environment as well as building.

To be continued (work in progress).

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Contents

Section 1A: computation of silencers with discontinued splitters (MODULE 1A of the software)

Section 2: computation of plane partitions (MODULE 2 of the software)

Section 3: computation of duct walls (MODULE 3 of the software)

Section 6: computation of bends (MODULE 6 of the software)

Section 7: computation of nozzle reflection (MODULE 7 of the software)

Section 8: computation of sound impact of a duct system (MODULE 8 of the software)

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General considerations

0.1: Introduction

What does the present user's manual aims at

The software SILDIS (Sound Impact Limitation Design for Industrialized Solutions) has been developed in order to allow (for users among the team ITS or elsewhere) the **prediction of acoustic and aerodynamic performances of dissipative silencers** and **the prediction of acoustic performances of plane partitions and ducts**.

The present user's manual aims at:

- providing the scientific and technical background of this software
- presenting the available features of this software
- answering the question: how to use SILDIS ?
- giving illustrative examples of the use of this software

Note 1: see also report [PhRxx-013x] (Sound Impact Limitation Design for Industrialized Solutions: a single Excel based software for a wide range of applications) to get answers to the question: why/when use SILDIS ?

Note 2: see also report [PhRxx-015x] Collection of soundproofing constructions systems: a companion to "User's manual for the software SILDIS"

Comments

SILDIS is a rolling tool, for which work is on progress in relation with existing features (being made available for users as soon as possible) and with features to come/to be modified, **involving possibly, during a transient period:**

- **the evaluation of some indicators of performance to be done thanks to several separate predictions** until sufficient feed-back allows to reduce the most appropriate separate predictions to the smallest amount necessary for the best use
- **some features to not be available** because not 100% implemented or not sufficiently verified (some features may also be available although not 100% verified indeed…)

In order to include the calculations in the general layout of the program, some models associated with known bibliographic sources have not been used, despite their level of interest from an academic point of view: SILDIS is sometimes based on simplified (although rarely simple) methods of computation, satisfying the requirements of the conditions of implementation and (hopefully) the requirements of the conditions of use of the program.

All unfavorable cases involved by the non limitation of the input data for different models are not always known with accuracy.

In case of an evaluation of an indicator of performances done thanks to several separate predictions, the preferred models (at the time of the writing) of the author of this manual are written in bold and underlined (like this for the model MOD: **MOD**)

SILDIS is a tool supposed to be shared by users being more or less experienced in computational noise control engineering, involving possibly for some users the feeling that some elements in this manual are not very familiar for them. Should this happen, those users would consider that such elements are dedicated to other users and would kindly focus on data foreseen to be entered by them in the software and on results - as mentioned above and detailed below - given to them by the software, that are - hopefully - not of that kind (**in case of doubt: please ask**).

Operating conditions / security level / safety

SILDIS is a PC program requiring the use of Excel 2010 (or a more recent version). The best operating conditions have been obtained with a computer whose technical characteristic are as follows: Intel®Core™i7 3920XM CPU @ 2.9 GHz 3.10 GHz ; 32 Go of RAM.

SILDIS is a program with a restricted access: see report [PhRxx-014x] (Procedure for the use of Excel based programs with a restricted access).

General layout of the program

The general layout of the program SILDIS is as shown on fig. 0.1a & fig. 0.1b below (cf. appendix for abbreviations).

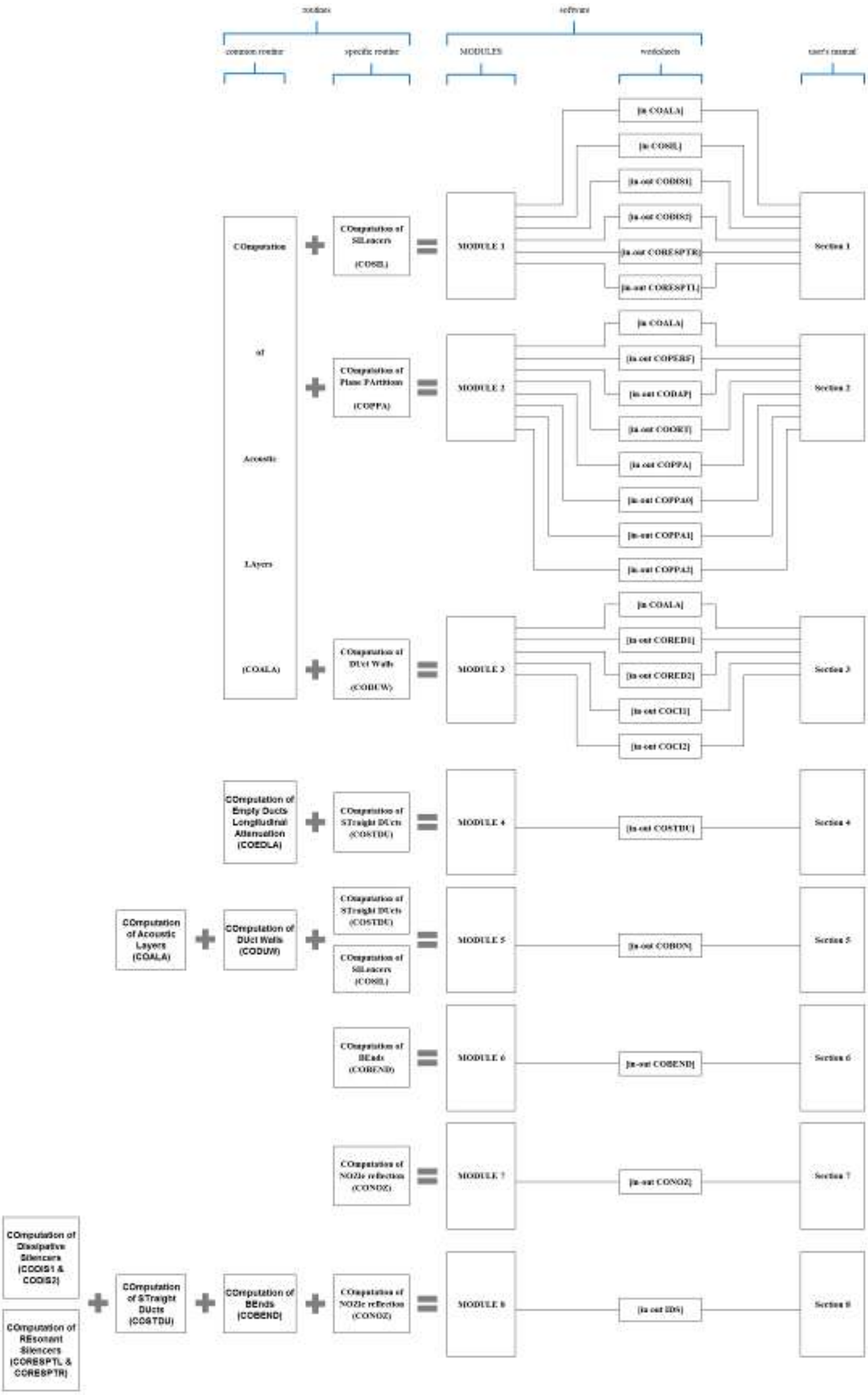
routines
software
common routine
specific routine
MODULES
worksheets
user's manual
COmputation of Acoustic LAyers (COALA)
COmputation of SILencers (COSIL)
MODULE 1
[in COALA]
[in COSIL]
[in-out CODIS1]
[in-out CODIS2]
[in-out CORESPTR]
[in-out CORESPTL]
Section 1
COmputation of Plane PArtition (COPPA)
MODULE 2
[in COALA]
[in-out COPERF]
[in-out CODAP]
[in-out COORT]
[in-out COPPA]
[in-out COPPA0]
[in-out COPPA1]
[in-out COPPA2]
Section 2
COmputation of DUct Walls (CODUW)
MODULE 3
[in COALA]
[in-out CORED1]
[in-out CORED2]
[in-out COCI1]
[in-out COCI2]
Section 3
COmputation of Empty Ducts Longitudinal Attenuation (COEDLA)
COmputation of STraight DUcts (COSTDU)
MODULE 4
[in-out COSTDU]
Section 4
COmputation of Acoustic Layers (COALA)
COmputation of DUct Walls (CODUW)
COmputation of STraight DUcts (COSTDU)
COmputation of SILencers (COSIL)
MODULE 5
[in-out COBON]
Section 5
COmputation of BEnds (COBEND)
MODULE 6
[in-out COBEND]
Section 6
COmputation of NOZle reflection (CONOZ)
MODULE 7
[in-out CONOZ]
Section 7
COmputation of Dissipative Silencers (CODIS1 & CODIS2)
COmputation of REsonant Silencers (CORESPTL & CORESPTR)
COmputation of STraight DUcts (COSTDU)
COmputation of BEnds (COBEND)
COmputation of NOZle reflection (CONOZ)
MODULE 8
[in out IDS]
Section 8

Fig. 0.1a

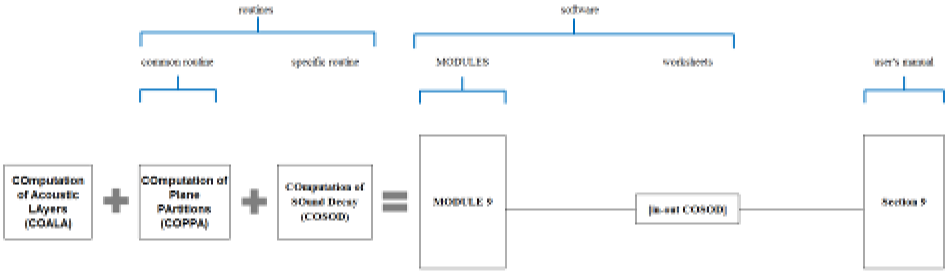

Fig. 0.1b

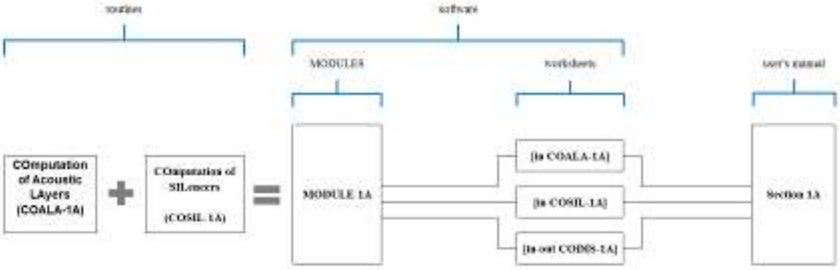

Fig. 0.1c

<u>**As far as MODULES 1 to 9 are concerned**</u>

A common routine referred to as COALA (COmputation of Acoustic LAyers) is associated with specific (complementary) routines:

- on the one hand: the routine COSIL (COmputation of SILencers), this association basing the features of the **MODULE 1** of the software (described in **the Section 1** of the present user's manual)
- on the other hand: the routine COPPA (COmputation of Plane PArtitions), this association basing the features of the **MODULE 2** of the software (described in the **Section 2** of the present user's manual)
- furthermore: the routine CODUW (COmputation of DUct Walls), this association basing the features of the **MODULE 3** of the software (described in the **Section 3** of the present user's manual)

The routine referred to ass COSTDU (COmputation of STraight DUcts) is basing the features of the **MODULE 4** of the software (described in the **Section 4** of the present user's manual).

The routine referred to as COSTDU (COmputation of STraight DUcts) and the routine COSIL (COmputation of SILencers) are associated with a specific (complementary) routine:

- the routine COBON (COmputation of Break Out Noise), this association basing the features of the **MODULE 5** of the software (described in the **Section 5** of the present user's manual)

The routine referred to as COBEND (COmputation of BENDs) is basing the features of the **MODULE 6** of the software (described in the **Section 6** of the present user's manual).

The routine referred to as CONOZ (COmputation of NOZzle reflection) is basing the features of the **MODULE 7** of the software (described in the **Section 7** of the present user's manual).

The routine referred to as IDS (COmputation of Impact of Duct Work) is basing the features of the **MODULE 8** of the software (described in the **Section 8** of the present user's manual).

All MODULEs 1 to 8 are encapsulated in a single file.

The routine referred to as COSOD (COmputation of SOund Decay) is basing the features of the **MODULE 9** of the software (described in the **Section 9** of the present user's manual).

MODULE 9 is encapsulated in a separate file.

<u>**As far as MODULES 1A is concerned**</u>

A routine referred to as COALA-1A (COmputation of Acoustic LAyers) is associated with specific (complementary) routine the routine COSIL-1A (COmputation of SILencers), this association basing the features of the **MODULE 1A** of the software (described in **the Section 1A** of the present user's manual)

MODULE 1A is encapsulated in a separate file.

Worksheets

The software SILDIS is configurated in order to allow the user to access to several worksheets as shown on fig. 0.1a, 0.1.b and 0.1.c above (in case of "in" in the name of a given worksheet, the user should be prepared to input data, in case of "out" in the name of a given worksheet, the user should be prepared to get results).

Input data

The software SILDIS is configurated in order to allow the user to input data by filling/modifying yellow cells (*), sometimes by the means of drop-down menus (**) allowing the selection of references of materials, engineering constants, models, conditions of the application… (***)

* something like that ** something like that

*** some users may not be allowed to input data by filling/modifying some yellow cells for the sake of simplicity

0.2: Scientific and technical background

System of units

The system of units used with the software SILDIS for input data and displayed results (and consequently the system of units used in the present document) is the International System of units, some conversions factors being given when useful

Reference conditions

Reference conditions are involved in the expression on the one hand of input data and on the other hand of results with the software SILDIS (different definitions of reference conditions being more or less currently used all over the world).

For the purposes of the present user's manual, the following terms and definition apply:

Normal conditions: set of conditions including a temperature $t_0^N = 0°C$ and a pressure $P_0^N = 101325$ Pa.

Note: with the software SILDIS, flow rates expressed in Nm3/h are related to normal conditions

(Test) room conditions (i.e. typically encountered in a room): conditions for which measurement of engineering data of materials (porous media, cloths, perforated protections, plates) are usually (sometimes implicitly) performed, namely with a temperature t_0* generally not too far from 20°C, with a pressure P_0* generally not too far from 10^5 Pa, and with an air speed not too far from 0 m/s.

Note 1: in the worksheets of the software (and consequently in the present document), "usual" refers to input data for (test) room conditions
Note 2: a unique (i.e. common) value of temperature and a unique (i.e. common) value of pressure (being input data themselves in order to allow to some users a fine tuning in some circumstances) are assumed for all "usual" input data.

Service conditions: conditions for which the design of the envisaged soundproofing equipment is performed, possibly influenced by various changes when compared to (test) room conditions, notably with a temperature sometimes far away from (test) room temperature or/and with a pressure sometimes far away from (test) room pressure or/and with an air speed sometimes far from zero.

Note: in the worksheets of the software (and consequently in the present document), "special" refers to input data for service conditions

Fluid

The fluid involved on the one hand: in pores of porous media, on the other hand: in perforations of perforated protections and generally speaking: in atmosphere is assumed to be in all cases (clean) dry air.

Note for dissipative silencers: the fluid of which the carriage is considered through the dissipative silencer is assumed to be (clean) dry air.

Electro-acoustic analogies

The (popular) application of an equivalent network is a convenient representation and a useful method for the solution of many tasks in relation with the computation of acoustic layers (based on electro-acoustic analogies with electrical circuits: sound pressure, particle velocity and acoustic impedance being respectively analogous to voltage, current and electrical impedance).

- **Terms and definitions**

For the purposes of the present user's manual, the following terms and definition apply:

Element: 1 porous medium or 1 cloth or 1 perforated protection or 1 thin plate (indeed: 1 or several identical thin plates treated as a whole)

Note: 1 element can consist of 1 or several acoustic layer(s) each (examples: a pair of identical plates with a negligible interspace is 1 element consisting of 2 acoustic layers; a plate with an extensional damping is 1 element consisting of 2 acoustic layers, etc…)
Set (of elements): stacking of several elements gathered for a sake of simplicity of implementation/use of the software (sometimes reduced to1 element).The position (rank) of each element is constant within each set.

Note 1 for dissipative silencers: each set (indexed from an impervious rigid back at the rear to the front: 1 to 4) consists (from the rear to the front) of up to 1 porous medium, up to 1 cloth, up to 1 perforated protection.

Note 2 for plane partitions: each set (indexed from the rear to the front: 1 to 4) consists (from the rear to the front) of up to 1 porous medium, up to 1 cloth, up to 1 perforated protection, and up to 1 (or several identical) thin plate(s). A complementary set (set 0) is used (at the rear of set 1) consisting of up to 1 thin plate (indeed up to 1 or several identical thin plates treated as a whole) backed by atmosphere or backed by an impervious rigid wall). *Remark: for the set 0, the number of identical plates only can be freely selected by the user - the material and the thickness being selected by the user among those of the plate(s) of the set 1 or of the set 2 -*

Maximum set index imax: index (up to 4) of the set located as far on the front side, taken into account for the computation (among the sets taken into account for the computation). The elements belonging to sets with an index **i≤imax** are taken into account for the computation under the condition of selected quantities of elements different of 0; the elements belonging to sets with an index **i>imax** are not taken into account for the computation whatever the selected quantities of those elements are (example: if **imax=1**, a perforated protection belonging to set 1 will be taken into account for the computation unless the considered quantity is 0; a perforated protection belonging to set 2 will not be taken into account for the computation even if the selected quantity is 1).

Acoustic structure: the whole stacking of acoustic layers of interest

Note 1 for dissipative silencers: the acoustic structure consists of elements (for which the selected quantity is not 0) belonging to sets 1 to **imax**. The acoustic structure is sometimes referred to as "lining", assuming an impervious rigid back for the considered duct and sometimes referred to as "splitter" (assuming a symmetry plane - opposite to the airway side - equivalent to an impervious rigid back: requiring sometimes for field applications a rigid centre plate implicitly supposed to be added to the real construction despite the lack of explicit corresponding input data with the software SILDIS)

Note 2 for plane partitions: the acoustic structure consists of elements (for which the selected quantity is not 0) belonging to sets 0 to **imax.** *Remark: for the set 0, the number of identical plates only can be freely selected by the user - the material and the thickness being selected by the user among those of the plate(s) of the set 1 or of the set 2 -*

- **Equivalent network**

The general equivalent circuit considered for the purposes of the routine COALA (COmputation of Acoustic LAyers) common to the COmputation of DIssipative Silencers (CODIS) and to the COmputation of Plane PArtitions (COPPA) with the software SILDIS is as shown on the figure 0.2 below (with Pi : sound pressure of the incident wave; Zis: internal source impedance; Zr: radiation impedance):

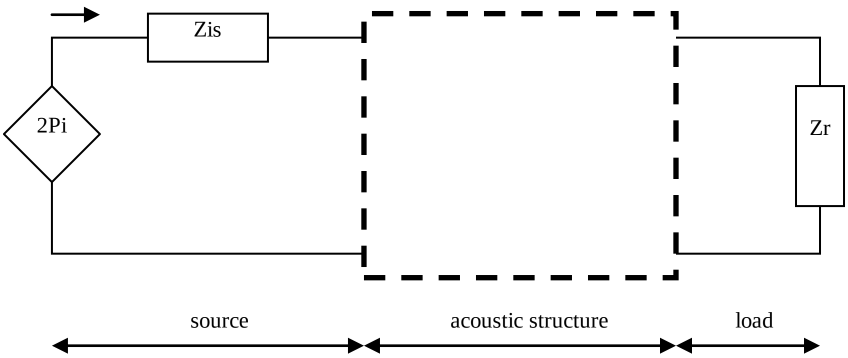

Fig. 0.2

The source represents the acoustic field (present in the upstream atmosphere) impinging on the acoustic structure.

The unique 4-poles representing the acoustic structure itself can be represented as an equivalent network, including several 4-poles.

Note 1 for dissipative silencers: the equivalent network is including 4 such 4-poles: the above mentioned sets indexed from 1 to 4 (the load being infinite in case of an impervious rigid back) see figure 0.3 below

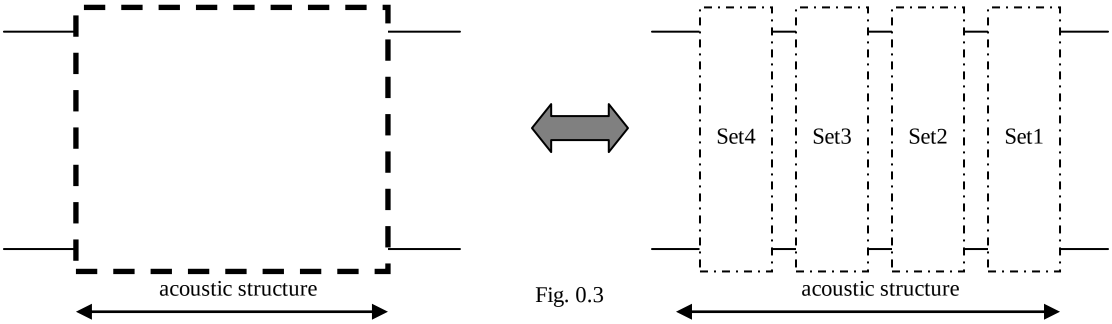

Fig. 0.3

The 4-poles representing the sets themselves can be represented as equivalent networks, consisting of a combination of 4-poles elements (such as porous media) and, by using an "old school" approach of 2-poles elements (series elements): such as cloths and perforated protections (see figure 0.4 below)

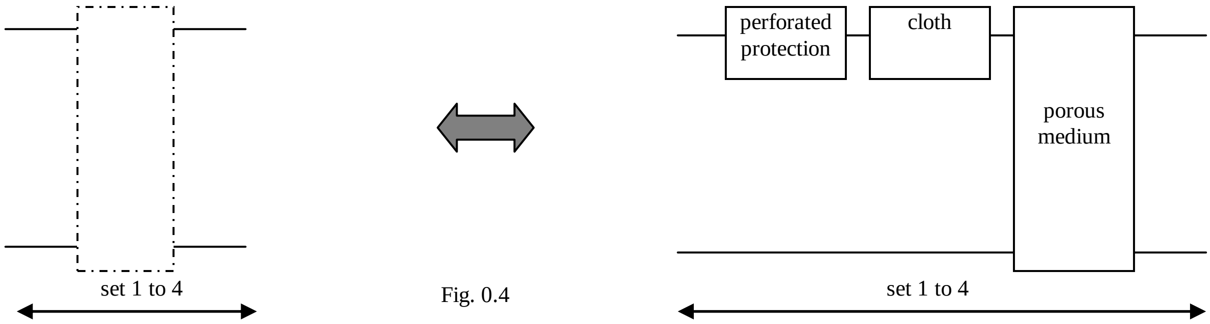

Fig. 0.4

By using a "new wave" approach: cloths, perforated protections are 4-poles elements (the quantities of corresponding series elements being set equal to 0 by the user in this case)

Note 2 for plane partitions: the equivalent network is including 5 such 4-poles: the above mentioned sets indexed from 1 to 4 and a complementary set indexed 0 (the load being either infinite in case of an impervious rigid back or the radiation impedance of air in case of an atmospheric back) (see figure 0.5 below) *Remark: for the set 0, the number of identical plates only can be freely selected by the user - the material and the thickness being selected by the user among those of the plate(s) of the set 1 or of the set 2 –*

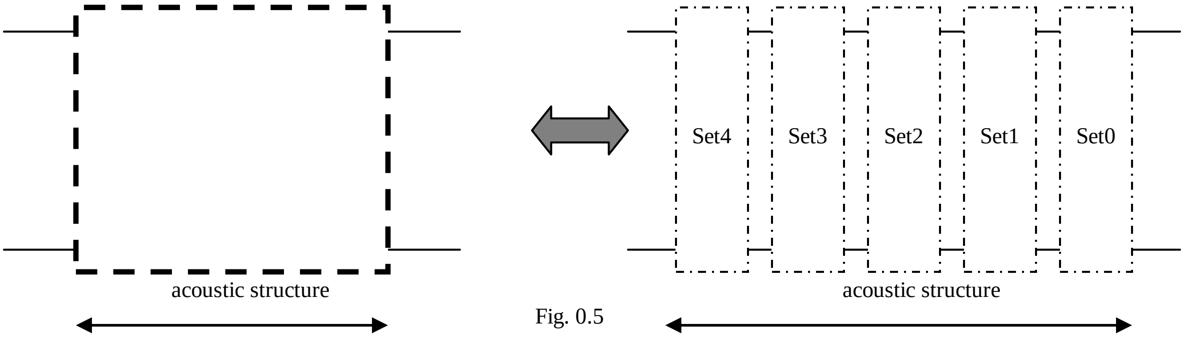

Fig. 0.5

The 4-poles representing the sets themselves can be represented as equivalent networks, consisting of a combination of 4-poles elements (such as porous media) and of 2-poles elements (series elements): such as thin plates and, by using an "old school" approach with other 2-poles elements (series elements): such as cloths and perforated protections (see figures 0.6 and 0.7 below)

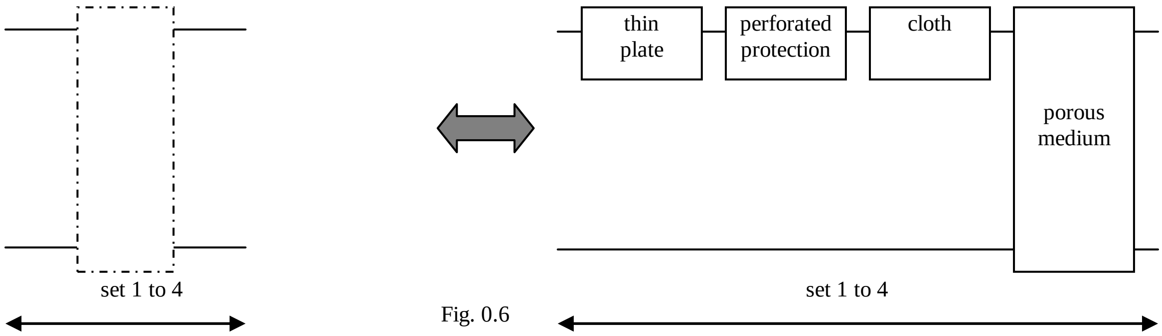

Fig. 0.6

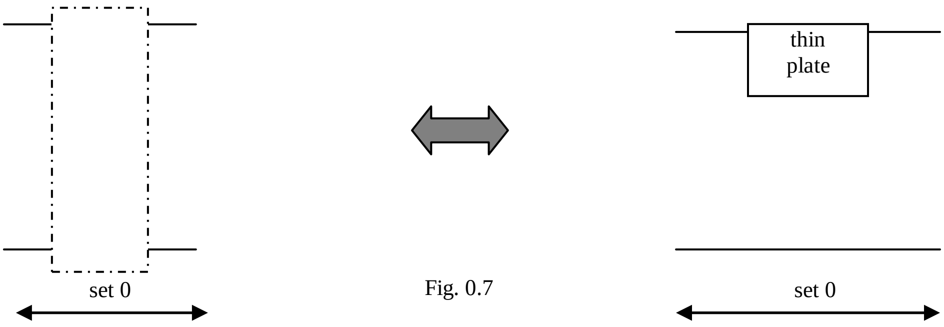

Fig. 0.7

By using a “new wave” approach: cloths, perforated protections are 4-poles elements (the quantities of corresponding series elements being set equal to 0 by the user in this case)

Remark regarding construction systems

Construction systems (for field applications: including sketches and nomenclatures) for which the design is possible with the software SILDIS are not described in an exhaustive manner in the present document, being the object of a separate document for a sake of simplicity.

One will see the document referenced Collection of soundproofing constructions systems: a companion to “User’s manual for the software SILDIS” illustrating the possibilities of use of the software for practical cases (report [PhRxx-015x])

Appendix to general considerations: list of symbols and acronyms

General

Cf. corresponding § in Section 1

Electro-acoustic analogies

Pi : sound pressure of the incident wave
Zis: internal source impedance
Zr: radiation impedance

Reference conditions

Cf. corresponding § in Section 1 for dry air

Miscellaneous

See also corresponding § in Section 1 and in Section 2

Acronyms

COALA: COmputation of Acoustic Layers

CODAP: COmputation of DAmped Plates
COORT: COmputation of ORThotropic plates
COPERF: COmputation of PERForated plates

COPPA: COmputation of Plane PArtitions
- COPPA0: with 0 thin plate in the acoustic structure
- COPPA1: with 1 thin plate in the acoustic structure
- COPPA2: with 2 thin plates in the acoustic structure)

COSIL: COmputation of SILencers

CODIS: COmputation of DIssipative Silencers
- CODIS1: attenuation accounted 1 time
- CODIS2: attenuation accounted 2 times

CORESPT: COmputation of REsonant Silencers with Pine-Tree splitters
- CORESPTL: COmputation of REsonant Silencers with Pine-Tree splitters with a Lateral lining
- CORESPTR: COmputation of REsonant Silencers with Pine-Tree splitters with a Rear lining

CODUW: COmputation of DUct Walls
- COCID: COmputation of Circular Duct walls
- CORED: COmputation of REctangular Duct walls

COEDLA: COmputation of Empty Ducts Longitudinal Attenuation

COSTDU: COmputation of Straight DUcts

COBON: COmputation of Break-Out Noise

COBEND: COmputation of BENDs

COSOD: COmputation of SOund Decay

CONOZ: COmputation of NOZzle reflection

IDS: computation of Sound Impact of Duct Systems

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Section 1: computation of silencers (MODULE 1 of the software)

1.1: Introduction

Terms and definitions

For the needs of the present user’s manual, the following terms and definition apply (see NF EN ISO 14163 Acoustics - Guidelines for noise control by silencers, 1999):

Silencer: device reducing the acoustic transmission in a duct, a pipe or an aperture, without preventing the carriage of the fluid

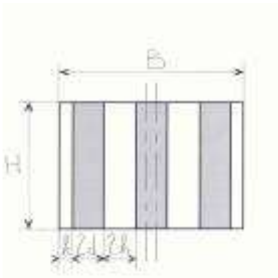
Dissipative silencer: silencer attenuating the wideband sounds with a relatively low pressure loss and converting partially the acoustic energy into heat by friction on tubes having a porous or fibrous structure

Resonant silencer: silencer producing an acoustic attenuation from weakly damped resonances of elements. The elements of the splitters can contain or not contain absorbing materials.

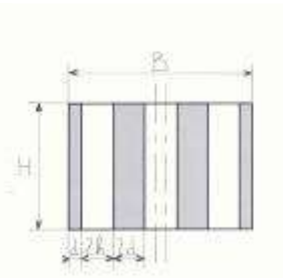
Mountings and geometry

Silencers having various cross sections are frequently used for industrial applications.

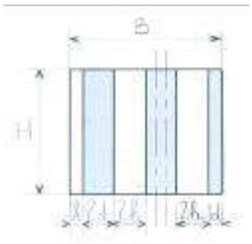
For dissipative silencers, the various mountings for which predictions can be done with the software SILDIS are shown in fig.1.1 and fig. 1.2



mounting R’’

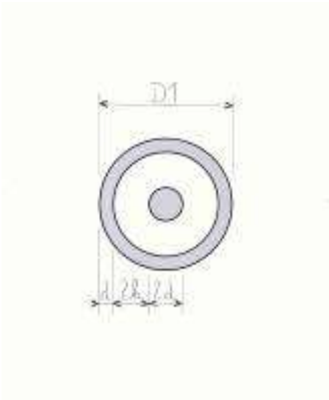


mounting R



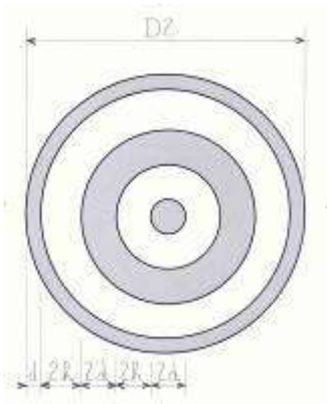
mounting R'

mounting C0 ½



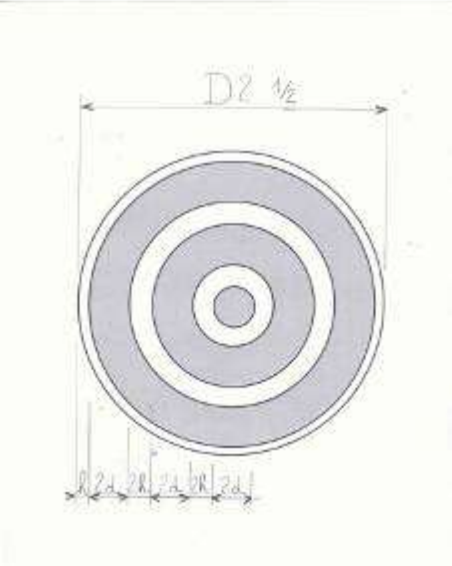
mounting C1

mounting C1 ½



mounting C2

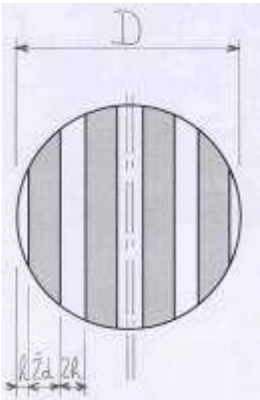
fig. 1.1 cf. worksheet CODIS1



mounting C2 ½

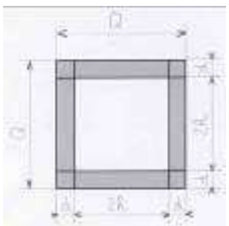
mounting C3

mounting C3 ½



mounting CR

fig. 1.1 (continue) cf. worksheet CODIS1



mounting Q

mounting C0

fig. 1.2 cf. worksheet CODIS 2

Key of the previous figures

d=2d/2: thickness of extreme inner lagging (for mountings R, C1, C2 only) = thickness of lining (for mounting Q, C0 only)
2d: thickness of central splitters (for mountings R, R'') = diameter of central pod (for mountings C1, C2 only) = thickness of intermediate splitter (for mounting C2 only)
h=2h/2: width of extreme air way (for mounting R''only)
2h: width of central airways (for mounting R, R'' only) = width of the airways (for mountings R, R'', C1, C2, Q)
$a=h*2*\pi^{-0.5}$
2a: width of airway (for mounting C0 only)
L: length of the silencer without aerodynamic extremities
N'': number of central splitters (for mounting R'' only); N'' = B / 2 / (d + h)
N: number of central splitters (for mounting R only); N = N'' – 1

Concerning the area of the duct upstream and downstream (above and below the silencer) A compared to the area of the overall section of the silencer Af, predictions with the software SILDIS can be done:

- for mountings R, R'', C2 with A = Af
- for mounting C1 with A = Af or with A = Af* < Af *)
- for mountings Q, C0 with A = Af* < Af *)

Section of the duct above and below the silencer A depending on mounting	R, R''	C1	C2	Q	C0
if A=Af	B*H	$\pi*(D1)^2/4$	$\pi*(D2)^2/4$	$(Q)^2$	$\pi*(D0)^2/4$
if A=Af* < Af *)	-	$\pi*(D1-2d)^2/4$	$\pi*(D2-2d)^2/4$	$(Q-2d)^2$	$\pi*(D0-2d)^2/4$

*2d being subtracted to the overall dimension of the silencer in order to obtain the corresponding dimension of the considered duct)

The direction parallel to the axis of the duct is referred to as **x**, the direction normal to the axis of the duct (along the thickness of the lining) is referred to as **y** according to the fig. 1.3 below (example for a mounting R)

In case of a rectangular silencer, the direction perpendicular to **x** and **y** is referred to as **z** according to the fig. 1.3 below (not considered for the computation with SILDIS)

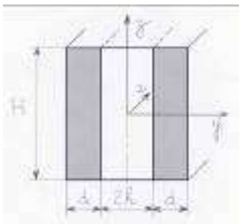
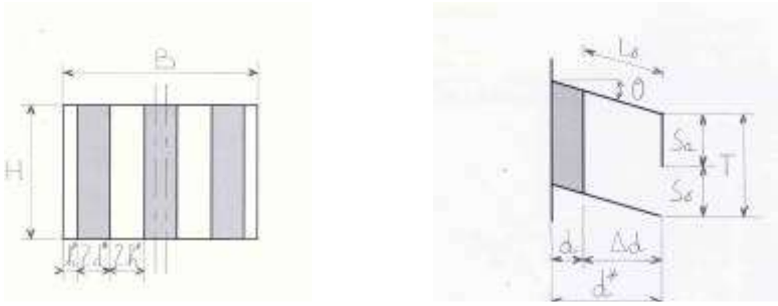
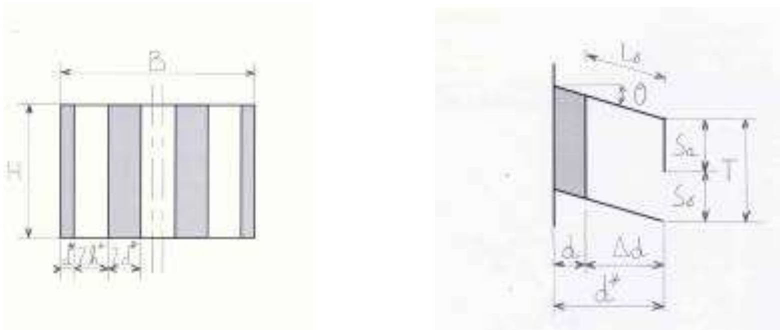


fig.1.3

For resonant silencers, the various mountings for which predictions can be done with the software SILDIS are shown in fig.1.4 and fig. 1.5

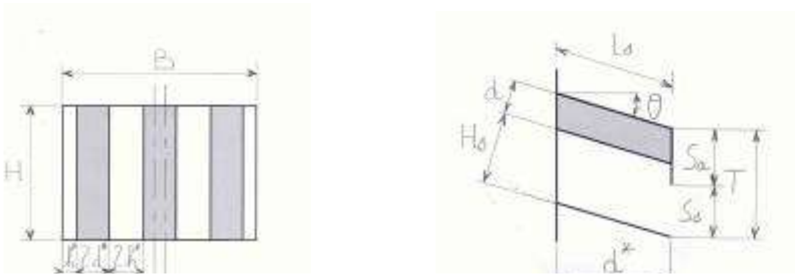


mounting RPTR''

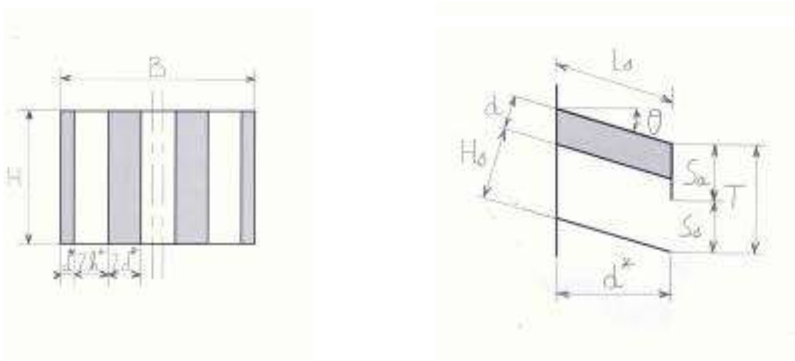


mounting RPTR

fig. 1.4 cf. worksheet CORESPTR



mounting RPTL''



mounting RPTL

fig. 1.5 cf. worksheet CORESPTL

<u>Key of the previous figures</u>

d*=2d*/2: thickness of extreme inner lagging (for mountings RPTR, RPTL only)
2d*: thickness of central splitters
h*=2h*/2: width of extreme air way (for mounting RPTR'', RPTL'' only)
2h*: width of central airways
L: length of the silencer without aerodynamic extremities
N''*: number of central splitters (for mounting RPTR'', RPTL'' only); N''* = B / 2 / (d + h)
N': number of central splitters (for mounting R only); N* = N''* – 1

Concerning the area of the duct upstream and downstream (above and below the silencer) A compared to the area of the overall section of the silencer Af, predictions with the software SILDIS can be done with A = Af

Section of the duct above and below the silencer A depending on mounting	RPTR, RPTR'' RPTL, RPTL''
A=Af	B*H

1.2: Scientific and technical background

The prediction of acoustic and aerodynamic performances of dissipative silencers with SILDIS is founded on a scientific and technical background in relation with:

- analytical models for taking into account the properties of materials and various physical phenomena useful on the occasion of the computation
- measurement results for feeding some of those models and for allowing the necessary improvement (through correction factors) of the correlation between some calculations and on site observations

For a rectangular silencer, the obtained results are comparable with the standardized measurement with the plane wave excited alone as much as possible: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units - Insertion loss, flow noise and total pressure loss (2004).

1.2.1 Thermodynamics and fluid dynamics:

- **Steps of the computation**

Step [a]

All computations have been gathered in this single step for the sake of simplicity.

- ***Bibliography (references) :***

[a1]	
[a2]	
[a3]	
[a4] -	
[a5]	

- ***Comments in relation with partial derivatives:***

Partial derivatives (and related quantities), which are usually employed to measure the equation of state of the fluid near the equilibrium state (with various notations according bibliographic sources) are written for the purpose of the present user's manual with the following notations:

- the **isothermal compressibility** of dry air is referred to as C_T

$$C_T = -\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T = \frac{1}{\rho}\left(\frac{\partial \rho}{\partial P}\right)_T$$

- the **isothermal bulk modulus** of dry air is referred to as K_T with $K_T=1/C_T$

- the **adiabatic compressibility** of dry air is referred to as C_s

$$C_s = -\frac{1}{\kappa V}\left(\frac{\partial V}{\partial P}\right)_T = \frac{1}{\kappa\rho}\left(\frac{\partial \rho}{\partial P}\right)_T \quad \text{because } C_s = C_T/\kappa$$

- the **adiabatic bulk modulus** of dry air is referred to as K_s with $K_s=1/C_s$

- the **coefficient of thermal expansion** of dry air is referred to as β

$$\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P = -\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_P$$

- ***Other comments:***

- when used the **density** of dry air ρ is computed according various models as shown in the table below:

model	MAR	**MEC**
source	[a1] using ideal gas law (derived from MARiottes's law) (*)	[a1] using a regression

* the **gas constant of dry air** R (J/kg/K) is set to 287 or **287.053** or 287.10 depending on the eponym selected model

- when used the **dynamical viscosity** of dry air η is computed according various models as shown in the table below:

model	SUT	VER	**MEC**	IDE
source	[a2] using SUTherland 's law)	[a4]	[a1] using a regression	[a2] using a regression
limiting temperature	-20 to 800 °C	?	-173.15 to 926.85 °C	-20 to 800 °C

Conversion factors	micropoise	centipoise	poise = g/cm/s	kg/m/s = Nsm-2
micropoise	1	10^{-4}	10^{-6}	10^{-7}
centipoise	10^{4}	1	10^{-2}	10^{-3}
poise = g/cm/s	10^{6}	10^{2}	1	10^{-1}
kg/m/s = Nsm-2	10^{7}	10^{3}	10	1

- when used the **kinematic viscosity** of dry air ν is computed from [a1]

Note : $\nu = \eta/\rho$

Conversion factors	centistokes = mm2/s	stokes = cm2/s	m2/s
centistokes = mm2/s	1	10^{-2}	10^{-6}
stokes = cm2/s	10^{2}	1	10^{-4}
m2/s	10^{6}	10^{4}	1

- when used the **adiabatic exponent** of dry air κ is computed according various models as shown in the table below:

model	INV	**MEC**
source	(*)	[a1] using a regression
limiting temperature	-	-73.15 to 926.85 °C

*κ is set to 1.399 or 1.400 or 1.401 or **1.402** depending on the eponym selected model

- when used the **specific heat (capacity) (at constant pressure)** of dry air c_p is computed according various models as shown in the table below:

model	MEC	**MEC2**	KRA
source	[a1] using a regression for a (the regression for c_p being in error)	[a1] using a regression for Pr (the regression for c_p being in error)	[a3] using a regression
limiting temperature	-73.15 to 926.85 °C	-173.15 to 926.85 °C	-20 to 800 °C

Conversion factors	J	cal
J	1	0.2388
cal	4.1868	1

- the following relation apply: $\kappa - 1 = \dfrac{\beta^2.T}{C_S.c_p.\rho}$
- when used the **thermal conductivity** of dry air λ is computed according various models as shown in the table below:

model	**MEC**	KRA
source	[a1] using a regression	[a3] using a regression
limiting temperature	-173.15 to 926.85 °C	-20 to 800 °C

Conversion factors	J	cal
J	1	0.2388
cal	4.1868	1

- when used the **diffusivity** of dry air a is computed from [a1]

  Note : $a = \lambda/\rho/c_p$

- when used the **Prandtl number** of dry air Pr is computed according various models as shown in the table below:

in case of model for c_p	**MEC**	MEC2	KRA
source	[a1] from η, c_p and λ	[a1] using a regression	[a3] from η, c_p and λ
limiting temperature	-73.15 to 926.85 °C	-173.15 to 926.85 °C	-20 to 800 °C

  Note : $Pr = \nu/a = \eta/\rho/a = \eta.c_p/\lambda$

- when used the **(adiabatic) sound velocity** in dry air c is computed from [a5]

  Note : $c = (K_s/\rho)^{0.5}$

- when used the **characteristic impedance** of dry air Z is computed from [a1]

  Note : $Z = \rho c$

1.2.2 Acoustics:

- **Bloc diagram for rectangular dissipative silencers and comments for other dissipative silencers and for resonators:** the computation scheme for rectangular dissipative silencers is as shown on fig 1.6 below

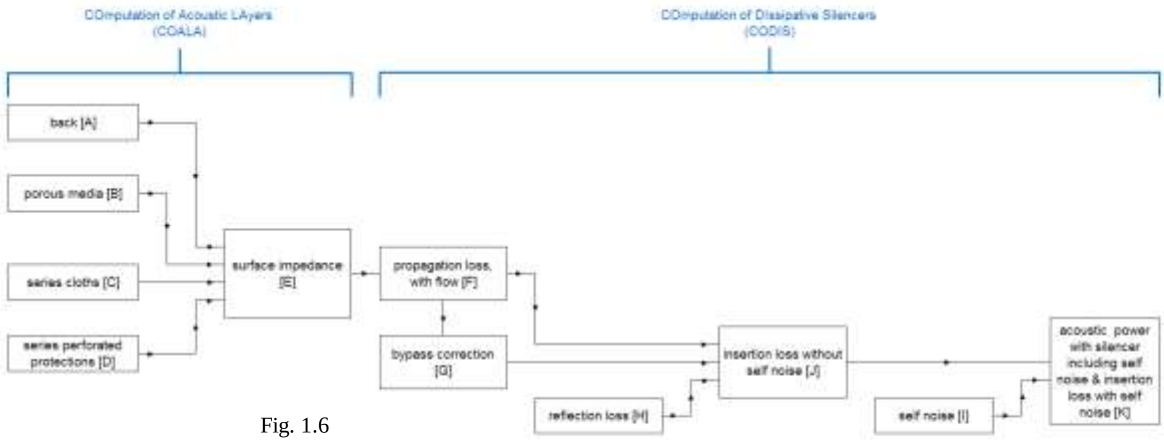


Fig. 1.6

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRxx-002x] pages 6 to 7, report [PhRxx-006x] pages 2 to 3, report [PhRxx-015x]

Note 2: the main steps (the steps involving a physical modeling) being referred to as [A] to [K] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity; the calculation is carried out with the hypothesis of plane waves, typically regarded as the least attenuated mode (only for step [H] are other modal contributions taken into account)

Note 3: analytical calculations are involved in steps [B] to [F] and [J] to [K]; empirical methods are involved in steps [G] to [I]

Note 4: step [F] is depending on the conditions of axial sound propagation inside the lining

Note 5: the bloc diagram above is suitable for rectangular dissipative silencers, whatever the considered mounting is among R, R'' .

Note 6 (**comments for other dissipative silencers**)(under the condition of same speed in the airways):

- for the mounting C1 and C2: the performance (from step [F] to step [K]) is extrapolated from the performance of the mounting R to which steps [A] to [E] are referring (not suitable for silencers with too small diameters)
- for the mounting Q and C0: the performance (of step [F]) is extrapolated from the performance of the mounting R to which steps [A] to [E] are referring (not suitable for silencers with too small diameters in case of mounting C0)

Note 7 (**comments for resonators**): a complementary step referred to as [L] is necessary between step [E] and step [F] allowing the computation of the admittance in the plane of the outlet side of (the neck of) the chamber

- **Steps of the computation**

Step [A]

This step aims at taking into account what is on the **back** (i.e. at the rear of the acoustic structure)

- ***Bibliography (references) :***

[A1]	

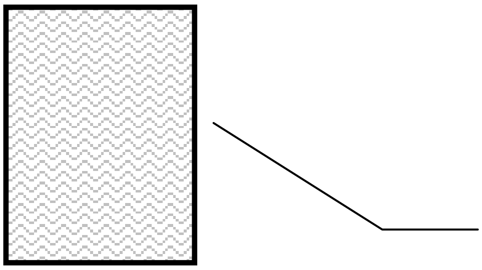
- ***Comments :***

No comment

Step [B]

This step aims at taking into account **porous media** used in the acoustic structure.

Fig. 1.5



- ***Bibliography (references) :***

[B1]	
[B2] -	
[B3] -	
[B4] -	
[B5]	
[B6]	
[B7]	
[B8]	
[B9] -	
[B10]	
[B11]	
[B12] -	
[B13]	

- ***Comments :***

The following governing equation is considered in the absorber layer (with notations adapted from various sources: will be specified on the occasion of a future revision of this user's manual):

$$\left(\frac{\partial^2}{(\Gamma_{ax}\,\partial x)^2} + \frac{\partial^2}{(\Gamma_{ay}\,\partial x)^2} - 1 \right) p_a\,(x,y,t) = 0$$

Where

p_a: pressure (Pa)
t: time (s)
Γ_{ax}: propagation constant in the x-direction (rad.m^{-1})
Γ_{ay}: propagation constant in the y-direction (rad.m^{-1})

- depending on the used model, some of the following parameters are taken into account in relation to the properties of a porous medium (sometimes only in a direction perpendicular to its surface): σ (Nsm^{-4}) airflow resistivity, ø porosity, α_∞ tortuosity, Λ' (m) thermal characteristic length, Λ (m) viscous characteristic length, RG (kg/m3) (bulk) density

model	DB	BH	AB	ORV	M76	M76+	M76+-	M84R	M84V
source	[B1]	[B2]	[B3]	[B4]	[B5]			[B6]	
parameters	σ	σ	σ	σ	σ ø	σ ø RG	σ ø RG	σ	σ
porous medium				polyester only	made of mineral fiber or of glass fiber only			rockwool and basalt wool only	glasswool only
comment related to frequency range							low frequency extension only		

model	M89	M89+	M89+-	**M89+***	**JKD**	AIR	CUM	JK2
source	[B7]				[B8]		[B9] (*)	[B8] (**)
parameters	σ ø	σ ø RG	σ ø RG	σ ø RG	σ ø α_∞ Λ' Λ	-	σ	σ ø α_∞ Λ' Λ
porous medium	made of mineral fiber or of glass fiber only				all kind	air only		perforated protection with round holes only
comment related to frequency range			low frequency extension only	with smoo thing				**Cancelled because was in error**
other comments (valid for a porous medium being **not** a perforated protection only)					model of added impedanc e should be set to ZER			
other comments (valid for a porous medium being a perforated protection only)					interactio ns with rear **porous** layer (*) and front **porous** layer (**) accounted by selecting appropriat e model of added impedanc e (cf. below)			
other comments (valid for a porous medium being a perforated protection only					in case of a perforated protection ,when one wishes to account interactio ns with rear **porous** layer (*) and front **porous** layer (**) like in [B12], RDE model for added impedanc e should be selected]			

* interaction with rear series cloth not accounted
** interaction with front series cloth not accounted

✓ the following models of added impedance:

Model of added impedance	RDE	**ROA**	ZER
source	[B12]	[B13]	
interaction	without additional resistance effects	with additional resistance effects	no interaction (*)

*the model ZER applies notably for modeling a front added length “blown away” by an airflow

* in case of normalized propagation constant Γ_{an} expressed as $\Gamma_{an} = a'/E^{\alpha'} + j * (1 + a''/E^{\alpha''})$ and in case of normalized characteristic impedance Z_{an} expressed as $Z_{an} = (1 + b'/E^{\beta'}) - j * b''E^{\beta''}$ the following relations apply:
$c_1 = b'$; $c_2 = -\beta'$; $c_3 = b''$; $c_4 = -\beta''$; $c_5 = a'$; $c_6 = -\alpha'$; $c_7 = a''$; $c_8 = -\alpha''$ with $E = \rho.f / \sigma$
where f is the frequency (Hz) and ρ is the density of air (kg/m3)
**see the comments concerning series perforated protections

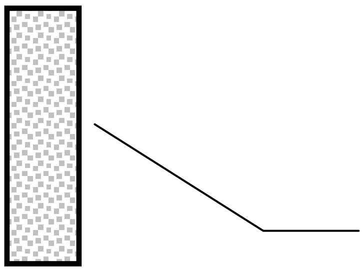
- no influence of the speed of the airflow is taken into account for the computation

Conversion factors	MKS Rayl/m = Nsm^{-4}	CGS units
MKS Rayl/m = Nsm^{-4}	1	10^{-3}
CGS units	10^{3}	1

Step [C]

This step aims at taking into account **series cloths** used in the acoustic structure.

Fig. 1.6



series cloth

- ***Bibliography (references) :***

[C1]	
[C2]	
[C3] -	
[C4] -	
[C5]	

- ***Comments :***

  - depending on the (general) used model, some of the following parameters are taken into account: superficial flow resistance Rs (Nsm-3), surface density M’ (kg/m2), parallel resistance (losses due to mounting) Rp (Nsm-3), E (N/m2) Young’s modulus, Poisson’s ratio ν, plate dimension a (m), as well as boundary conditions

general model	PLATE 1	PLATE 2	PLATE 3	PLATE 4	FRO
parameters	M’ E ν a boundary conditions	M’ E ν a boundary conditions	M’ E ν a boundary conditions	M’ E ν a boundary conditions	Rs M’ Rp
comment	as entered for thin plate 1 except for M’ (computed from ρ as entered for thin plate 1 and from d as entered	as entered for thin plate 2 except for M’ (computed from ρ as entered for thin plate 2 and from d as entered	as entered for thin plate 3 except for M’ (computed from ρ as entered for thin plate 3 and from d as entered	as entered for thin plate 4 except for M’ (computed from ρ as entered for thin plate 4 and from d as entered	

	for cloth 1)	for cloth 2)	for cloth 3)	for cloth 4)	

- for (general) model PLATE 1, PLATE 2, PLATE 3 and PLATE 4, boundary conditions are taken into account using various models

general model	CE	SSE
comment	Clamped Edges	Simply Supported Edges

- for (general) model FRO only, using electro acoustic analogies, complementary impedances can be accounted (for some predictions to be done in relation with the COomputation of Acoustic LAyers), with respect to the base impedance Zbase= Rs’ (with Rs’=superficial flow resistance): see fig.1.7

  - a parallel reactance jM’ω (Nsm-3)
  - a parallel resistance (losses due to mounting conditions) Rp’ (Nsm-3)

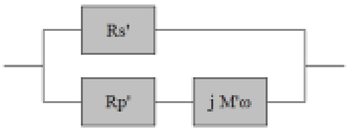


fig.1.7

Particular cases

	cloth, fabric according to [C3]	closed foil according to [C3]
Rs’ (Nsm^{-3})	free input	∞
Rp’ (Nsm^{-3})	0	0
M’ (kg/m2)	free input	free input

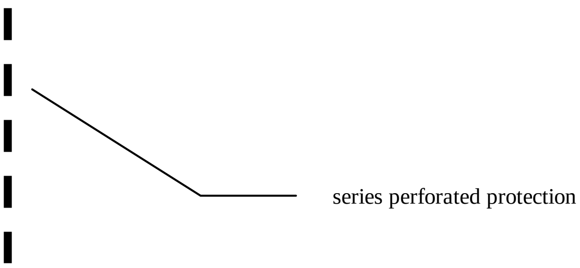
Note: <u>no</u> influence of the speed of the airflow is taken into account for the computation

Conversion factors	MKS Rayl = Nsm^{-3}	CGS units
MKS Rayl = Nsm^{-3}	1	10^{-1}
CGS units	10	1

Step [D]

This step aims at taking into account **series perforated protections** used in the acoustic structure.

Fig. 1.8



- ***<u>Bibliography (references) :</u>***

[D1]	
[D2] -	
[D3]	
[D4]	
[D5] -	
[D6] -	
[D7]	
[D8]	
[D9] -	

Comments :

- depending on the used (general) model, some of the following parameters are taken into account in relation with the properties of a perforated protection: d (m) diameter of the holes/width of the slits, t (m) thickness, ε open area ratio; depending on the used (general) model, various effects are (or are <u>not</u>) taken into account

general model	DYM	L+C	MOI	ICH
parameters	d t ε	d t ε	d t ε	d t ε
source	[D1]	[D2]	[D3],[D4]	[D3],[D4],[D5]
comment (general)	in contact with air only, holes circular only, square array only	in contact with air only, holes circular only, square array only	in contact with a porous layer (at the front and/or at the rear), with various geometries	in contact with a porous layer (at the front and/or at the rear), with various geometries
comment regarding the calculation of impedances			total impedance calculated as the sum of the impedance at the rear (using appropriate effective density) + tunnel impedance + impedance at the front rear (using appropriate effective density)	total impedance calculated using appropriate effective density accounting interactions at rear and at front
comment regarding the porous layer at the rear and at the front			even if of set index <imax, even if of thickness zero, the nature of the porous layer at the rear and at the front is accounted	even if of set index <imax, even if of thickness zero, the nature of the porous layer at the rear and at the front is accounted
other comment			MOI and ICH seems to provide identical results in case of a perforated sheet with round holes and in case of the use of the simplified model for the tunnel model MOI and in case of input data for the model MOI with tortuosity 1 and characteristic length appropriate	

- with the general model MOI the effects of the interaction of the perforated protection with a porous layer are taken into account by the means of:
    - ✓ an added length (increasing the mass of the vibrating air in the neck), depending on the geometry of the perforation:

Model of added length according the perforation geometry	COA	COB	COC	COJ	COM	**<u>CHC</u>**	CHM	CAR	FEM	FED	ZER
source	[D3]	[D2]	[D6]	[D9]	[D7]	[D6]	[D7]	[D7]	[D7]	[D8]	
Geometry of the perforation	circular, square array					circular, hexagonal array		square	infinite slot		
Open area ratio ε	<0.16		<0.785			<0.906		<0.16			no added length

✓ the following models of added impedance:

Model of added impedance	RDE	**ROA**	ZER
source	[D5]	[D7]	
interaction	without additional resistance effects	with additional resistance effects	no interaction (*)

*the model ZER applies notably for modeling a front added length "blown away" by an airflow

- using electro acoustic analogies, complementary impedances can be accounted (for some predictions to be done in relation with the COmputation of Acoustic LAyers) with respect to the base impedance Zbase: see fig.1.9

  - a series resistance R'' (Nsm-3) for models MOI and ICH
  - a parallel reactance jM''ω (Nsm-3)
  - a parallel resistance (losses due to mounting conditions) Rp'' (Nsm-3)

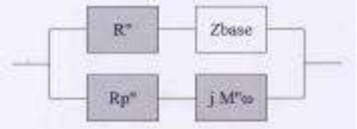


fig.1.9

Note: the recourse to a complementary parallel reactance jM''ω and to a complementary parallel resistance (losses due to mounting conditions) Rp'' can be envisaged in order to try to improve all general models listed above

Particular cases

	Special cases	often (in case of pure models of added length among those listed above)
R" (Nsm^{-3})	free input	0
Rp" (Nsm^{-3})	free input	∞
M' (kg/m2)	free input	∞

- simplified tunnel model is appropriate in case of thickness of the perforated sheet sufficiently low (simplified tunnel model not based on the comprehensive calculation using cascade). Simplified tunnel model is used in [D3], [D4], [D5], [D7]

- no influence of the speed of the airflow is taken into account for the computation (except * above)

Step [E]

This step aims at predicting the **surface impedance of a multilayered acoustic structure** (including porous media, series cloths and series perforated protections with a back selected in a way appropriate for the considered simulation).

- ***Bibliography (references) :***

[E1]	
[E2]	
[E3]	

- ***Comments :***

It has been taken into account:

- that the most sophisticated lining of interest for the applications foreseen at ITS (or elsewhere) consists of a 4 layers filling (see report [PhRxx-006x]):

- 2 layers of porous media
- 1 layer of cloth
- 1 layer of perforated sheet (being presently with diameter of holes 3mm in a hexagonal array with a perforation rate of 32 % thickness 1.5mm)

- the rear boundary condition for the arrangement of materials of interest for the COmputation of DIssipative Silencers:

- either considered without a symmetry plane opposite to the airway side (case of a lining with an impervious rigid back)
- or considered with a symmetry plane opposite to the airway side (case of a 1/2 splitter, requiring sometimes for field applications a sufficiently thick rigid centre plate implicitly supposed to be added to the real construction when required despite the lack of more explicit corresponding information in the present document), with an equivalence of this configuration to the previously mentioned one

▪ possible other useful arrangements of materials (for other predictions to be done in relation with the COmputation of Acoustic LAyers, not only in the context of COmputation of DIssipative Silencers)

Consequently (see figure 1.10 below, taking into account the present status of implementation of the software):

▪ a variable (from 1 to 4) number of sets of elements is considered for the computation, the sets being indexed from an impervious rigid back to the front (airway side): 1 to 4

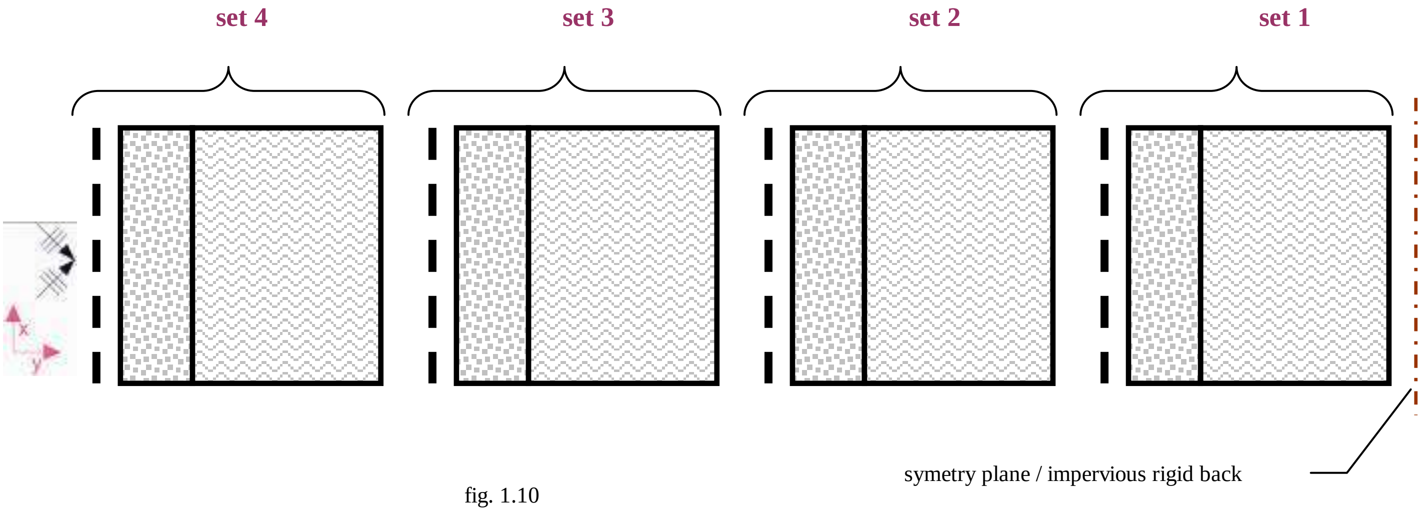


fig. 1.10

▪ each set consists (from the rear to the front) of up to 1 porous medium, up to 1 series cloth and up to 1 series perforated protection (the "series" concept being in relation with electro-acoustic analogies basing equivalent network): see figure 1.11 below.

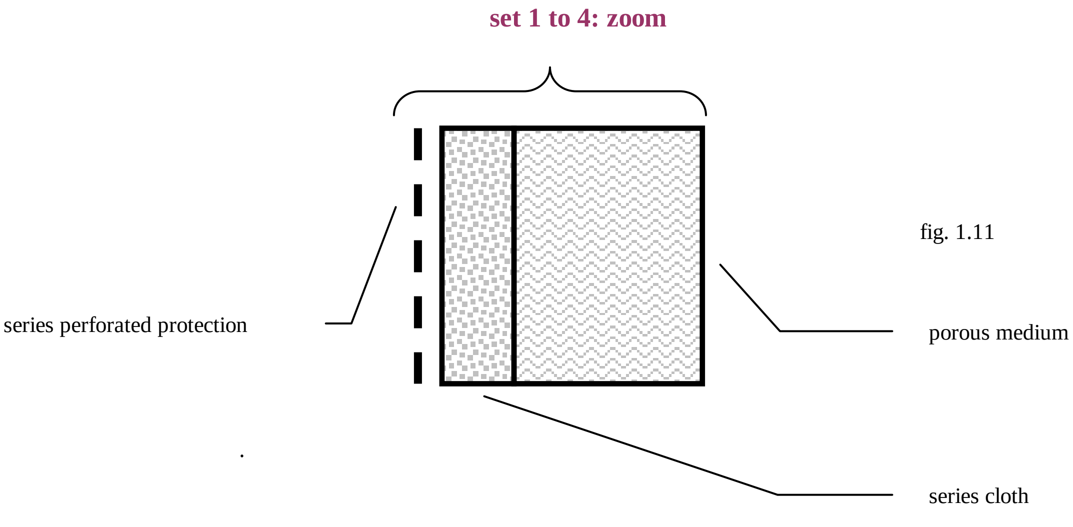


fig. 1.11

▪ the surface impedance of the acoustic structure with an impervious rigid back is calculated above the set **imax**: the COmputation of the DIssipative Silencer is performed for an acoustic structure (with an impervious rigid back) including sets from **1** to **imax** **(with 1 ≤ imax ≤ 4)**

The less complicated models available for taking into account the physical properties of a porous medium are based on the hypothesis of homogeneity in directions parallel to and perpendicular to the surface of the material (i.e. same properties in directions **x**, **y** and **z**). But some porous media (including some stone wools, some glass wools) are known to be non homogeneous in directions parallel to and perpendicular to the surface of the material having (in particular) an airflow resistivity normal to laminae of fibers $\boldsymbol{\sigma_N}$ and an airflow resistivity parallel to laminae of fibers $\boldsymbol{\sigma_P}$ that can notably differ (with $\boldsymbol{\sigma_P}$ reaching only 0.5*$\boldsymbol{\sigma_N}$ sometimes). So, in this case, the airflow resistivity of a material non homogeneous in directions parallel to and

perpendicular to its surface that would be known only thanks to a measurement normal to laminae of fibers (as often carried out) may be insufficiently known (for some design applications): for example the (sometimes useful) average value 0.5*($\boldsymbol{\sigma_N}$+$\boldsymbol{\sigma_P}$) would be only 0.75*$\boldsymbol{\sigma_N}$ with a ratio $\boldsymbol{\sigma_P/\sigma_N}$ of 0.5). This (a difference along the direction normal or parallel to the laminae) is also the case for other properties of numerous materials.

In the software SILDIS, a possible inhomogeneity in directions parallel to and perpendicular to its surface (i.e. different properties - depending on the used model - in directions **x** and **y**) is considered (for the routine COmputation of DIssipative Silencers) for the porous medium of set 1 (porous media for sets 2 to 4 being considered homogeneous in directions parallel to and perpendicular to the surface).

Note 1: each layer is assumed to not be glued to another

Note 2: concerning the perforated protection of the set **i**, the porous medium taken into account with the models of added impedance ROA and RDE is:

- at the rear: the porous medium of set **i**
- at the front: the porous medium of set **i+1** if **i<4** (<u>even if **i+1>imax**</u>: the selection of a reference different of AIR for the porous media of set **i** such as **i>imax** is highly discouraged) or the front atmosphere if **i=4**

Note 3: the use in practical cases (and the corresponding prediction of performance) of a perforated protection in contact with something else than a porous medium (that can be air at the front or a thin wire mesh spacer at the rear in some cases) is highly discouraged

- for the total thickness of the acoustic structure **d** the following formula apply:

$$\mathbf{d} = \sum_{\mathbf{i=1}}^{\mathbf{imax}} \mathbf{d_i} + \sum_{\mathbf{i=1}}^{\mathbf{imax}} \mathbf{I'_i * d'_i} + \sum_{\mathbf{i=1}}^{\mathbf{imax}} \mathbf{I''_i * d''_i}$$

d_i (resp. d'_i and d''_i) = thickness of the porous medium (resp. the series cloth and the series perforated protection) of set i
I'_i (resp.Id$''_i$) = 0 or 1 depending on the incorporation (or not) of the considered element of set i in the acoustic structure (omitted in the worksheets displays of the software for the sake of simplicity)

Note: this formula is compatible with the definition of **d** given in § **1.1)**

Step [F]

This step aims at calculating the **propagation loss with flow of the silencer**.

- ***<u>Bibliography (references) :</u>***

[F1]	
[F2] -	
[F3] -	
[F4]	
[F5]	

- ***<u>Comments :</u>***

The following governing equation is considered for the free duct (with notations adapted from various sources: will be specified on the occasion of a future revision of this user's manual):

$$\left(\Delta - \frac{1}{c_0^2}\frac{D^2}{Dt^2}\right) p(x,y,t) = 0$$

Where

c_0: (adiabatic) velocity of sound (ms^{-1})
p: pressure (Pa)
t: time (s)

$$\Delta = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$$

$$\frac{D}{Dt} = c_0\left[jk_0 + M\frac{\partial}{\partial x}\right] \textit{ with}$$

k_0: wave number (rad/m)
M: Mach number

- **conditions of the propagation of sound inside the absorbing material (for dissipative silencers)**

  - a sound propagation exists in the lining of a dissipative silencer, in a direction **y** (taken into account in the software SILDIS), depending on **σy** that is the flow resistance of the lining in the direction **y** : the attenuation of a dissipative silencer is always depending on this phenomenon (not only sometimes)
  - without transverse very thick metal sheets (with a very short distance between them: below 1/4 (maybe 1/6 ?) of the wavelength corresponding to the frequency of interest) acting as partitions, a sound propagation exists in the lining, in a direction **x**, depending on **σx** that is the flow resistance of the lining in the direction **x.** Consequently, the following cases are of interest: **σx1/σy1**=∞ (absorber locally reacting) (*), **σx1/σy1**=1 (absorber bulk reacting), **σx1/σy1**=variable being the general case including the previous cases

  * the case of an axial wave propagation inhibited by transverse very thick metal sheets (with a very short distance between them) acting as partitions is also referred to as **σx1/σy1**=∞ whatever the properties of the absorber are

- **complementary definitions in relation with the cross section of the silencer**

  - the total number ξ of cloths and perforated protections accounted as porous media i.e. <u>not</u> accounted as series cloth (resp. series perforated protections) using electro acoustic analogies is considered:

    - ✓ with an "old school" approach, **ξ=0** (since cloths and perforated protections are accounted exclusively as <u>series</u> cloths and <u>series</u> perforated protections using electro acoustic analogies)
    - ✓ with a "new wave" approach, **ξ≠0** (possibly): if some cloths or some perforated protections are (in some cases) accounted as porous media

  - consequently, the following definitions apply:

    ilim: limit set index (indeed: limit between **dlocal** and **hlocal**: see below) with 1≤ **ilim** ≤ **imax**

    - ✓ with an "old school" approach, **ilim = imax**
    - ✓ with a "new wave" approach, **ilim** has to be selected (by the user) such as **ilim = imax**- ξ

    dlocal: such as $$\mathbf{dlocal} = \sum_{i=1}^{ilim} \mathbf{d_i}$$ with d_i = thickness of the porous medium of set i

    dbulk: such as **dbulk** = **d1 (**thickness of porous medium of set 1)

    <u>Numerical application:</u> for a dissipative silencer with a rectangular cross section having rectangular splitters of thickness 2d such as 2d-2d'1=200mm made of one porous medium with a cloth of thickness d'1=5/100 mm

    - ✓ with an "old school" approach: **imax**=1;**ξ=0; ilim**=1;**dlocal**=200mm
    - ✓ with a "new wave" approach: **imax**=2;**ξ=1; ilim**=1;**dlocal**=200mm

  - the following definitions also apply in case of rectangular dissipative silencers and in case of mounting Q:

    hlocal = d + h – dlocal ; hbulk = d + h – dbulk

  - the following definitions apply in case of round dissipative silencer without a central pod (mounting C0):

    alocal = d + a – dlocal ; abulk = d + a – dbulk

  - the following definitions also apply in case of mounting RPTL, RPTL''

    Hslocal = d + Hs – dlocal ; Hsbulk = d + Hs – dbulk

- **determination of the propagation loss**

  The propagation loss (**Da** in dB/m) is basically computed at frequency steps of 1/21 octave (then averaged per 1/3 octave frequency band) for the fundamental mode (being considered as the least attenuated mode), the cut off frequency for the first higher mode **fco** depending on the speed of sound **c**, the Mach number in the airways **M**, and the geometry of the duct (see [F5])

  - ✓ *for the mountings R,R'*, $\mathbf{fco = 0.5 * c_0 / max\ [B,H] * (1- M^2)^{0.5}}$

- ✓ *for the mounting C1 (resp. C2)*, **fco = 0.586 * c_0 / D'1 * (1- M^2)$^{0.5}$** resp. **fco = 0.586 * c_0 / D'2 * (1- M^2)$^{0.5}$** In case of an area of the duct above and below the silencer A equal to the area of the overall section of the silencer Af, **D'1=D1** else **D'1=D1-2d** (resp. **D'2=D2** else **D'2=D2-2d**)

- ✓ *for the mountings Q*, **fco = 0.5 * c_0 / Q' * (1- M^2)$^{0.5}$** In case of an area of the duct above and below the silencer A equal to the area of the overall section of the silencer Af, **Q'=Q** else **Q'=Q-2d**

- ✓ *for the mounting C0*, **fco = 0.586 * c_0 / D'0 * (1- M^2)$^{0.5}$** In case of an area of the duct above and below the silencer A equal to the area of the overall section of the silencer Af, **D'0=D0** else **D'0=D0-2d**

The determination of the propagation loss is done (depending on the choice of the user) for one among the following cases,

σx1/σy1=∞ (absorber locally reacting), depending on **dlocal** and **hlocal (**resp. **alocal** for mounting C0**)**
σx1/σy1=1 (absorber bulk reacting), depending on **dbulk** and **hbulk (**resp. **abulk** for mounting C0**)**
σx1/σy1=variable (for an inhomogeneous absorber in directions parallel to and perpendicular to its surface including the cases of an absorber locally reacting and the case of an absorber bulk reacting with appropriate values of **σx1/σy1**), depending on **dbulk** and **hbulk (**resp. **abulk** for mounting C0**)**

- **particular case** for **imax=1** (i.e. only one porous medium in the lining)**, σx1** (resp. **σy1**) being the flow resistivity of the porous medium of set 1 in the **x (**resp. **y)** direction:

  For the case **σx1/σy1**=1 and for the case **σx1/σy1**=variable, a minimum flow resistance **r>rmini** is required with **r** = **σy1*d1/Z_0 (d1** being the thickness of the porous medium of set 1, **Z_0** being the characteristic impedance of air). Otherwise some important discontinuities may appear in the curves showing the propagation loss, and some accuracy of some displayed results may be anticipated: attention has to be paid that no such important discontinuity occurs this will be detailed in a future revision of the user's manual (perhaps)

- **particular case** for **imax>1** (i.e. more than one porous medium in the lining)

  For the different mountings, the determination of the propagation loss can be done for the following cases, **σxi** (resp. **σyi**) being the flow resistivity of the porous medium of set **i** in the **x (**resp. **y)** direction:

  σx1/σy1=∞ (absorber locally reacting) and **σxi/σyi**=∞ for **i>1** (absorbers locally reacting), depending on **dlocal** and **hlocal (**resp. **alocal** for mounting C0**)**
  σx1/σy1=1 (absorber bulk reacting), and porous media of sets with **i>1** accounted as series porous media (i.e. porous media acting as series impedances: see remark and fig. 1.9 below) depending on **dbulk** and **hbulk (**resp. **abulk** for mounting C0**)**
  σx1/σy1=variable (inhomogeneous absorber in directions parallel to and perpendicular to its surface including the case of an absorber locally reacting and the case of an absorber bulk reacting with appropriate values of **σx1/σy1**), and porous media of sets with **i>1** accounted as series porous media (i.e. porous media acting as series impedances: see remark and fig. 1.9 below) depending on **dbulk** and **hbulk (**resp. **abulk** for mounting C0**)**

  Remark: the conditions of the propagation of sound inside an absorbing material are considered only with respect to a single (given) porous medium. For **σx1/σy1**=1 or **σx1/σy1**=variable, the other layers (whatever they are, if different of the porous of **set1**) have consequently to be taken into account (using the electro acoustic analogies) as series impedances. Consequently, porous media of sets **i>1** are turned into series impedances in the following way: the surface impedance obtained above the porous medium of **set 1** is substracted to the surface impedance above set **imax** in order to get a series impedance that can be added to the 4-pole consisting of the porous medium of **set 1** (see fig 1.12 below)

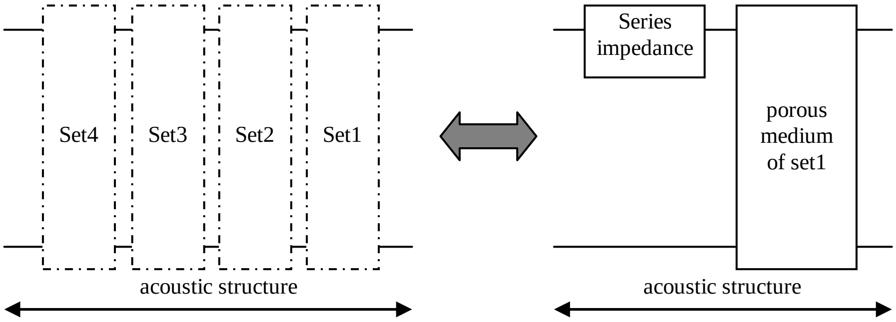


Fig. 1.12

- **influence of air flow**

The presence of airflow modifies the propagation loss: the computation is done with the hypothesis of a uniform air flow (supposed to not be rotational). Concerning flow rates and air speeds: a positive value is related to a direction of airflow equal to the direction of propagation of sound, a negative value is related to a direction of airflow opposite to the direction of propagation of sound

Step [G]

This step aims at taking into account a **bypass correction** (i.e. a limitation of the propagation loss in case of a length of the silencer over 1m: indeed, compared with the estimation obtained with an hypothesis of proportionality of the performance to the length of the silencer, in order to predict an insertion loss).

- ***Bibliography (references) :***

[G1] -	
[G2] -	
[G3]	

- ***Comments :***

The bypass correction (**Dk** in dB) is basically computed at frequency steps of 1/3 octave:

for L≤1m: Dk = 0 and **for L>1m: Dk = ΔD * (1 – L)** with **ΔD** in dB/m

- **general case**

An extrapolation of the original value of **ΔD** mentioned in [G1] is used for SILDIS, allowing calculations in an extended range of values of **σy1** for values of Λ=d/h to be précised on the occasion of a future revision of this user's manual

Note 1: the data pool used for the determination of the original value of **ΔD** mentioned in [G1] is related to splitters filled with 1 porous medium with a flow resistivity **σx1 =? σy1** from 9 to 15 $kNsm^{-4}$: no influence of the speed of the airflow seems to be taken into account for the computation, no influence of a series cloth seems to be taken into account for the computation, no influence of a series perforated protection seems to be taken into account for the computation

Note 2: in [G3] is mentioned for [G2] basing [G1] complementary information. The data pool used for **ΔD** is related to splitters "in 1 piece" with a thickness 2d=0.1 or 2d=0.2 m with Λ=d/h=0.5 to 4

Model	**FRO**	ZER
Bypass correction	as above	no limitation

*although at the time of the present user's manual the conditions of the measurement of the data pool ([G1],[G2]) are not known with accuracy, one can consider that: **Dk = Dk1 + Dk2** (the 2 terms being presently not known separately) with:

✓ **Dk1** to be accounted for the vibration transmission along the duct wall, for the sound transmission over the duct wall, for the vibration transmission along the splitter frame (as described in [G1] and for the imperfection of the interface between the lining and the duct

✓ **Dk2** to be accounted for the inhomogeneity of the used absorber in directions parallel to and perpendicular to its surface: a unique model is used for taking into account the limitation of propagation whatever **σx1/σy1** is (may be that this correction should be used only in the case of an inhomogeneous absorber in directions parallel to and perpendicular to its surface when the hypothesis **σx1/σy1**=1 is used for the computation).

For those reasons, the value obtained by the means of the unique model FRO has to be considered as a typical general estimation of the limitation of the propagation loss useful when no accurate regression is available for a silencer with a particular filling and particular modalities of construction (this is often the case)

- **particular cases:**

  - *for the mounting R''*, the bypass correction is supposed (in all cases) to be equal to the bypass correction calculated for the mounting R (all things being also equal)

  - *for the mounting C1,C2*, the bypass correction is supposed to be equal to the bypass correction calculated for the mounting R under the condition of an equal speed in the airways (all things being also equal)

- *for the mounting Q, C0*, the bypass correction (normalized to **Da**) is extrapolated from the bypass correction calculated for mounting R under the condition of an equal ratio **d/h**

- *for the mounting RPTR'' (resp. RPTL'')*, the bypass correction is supposed (in all cases) to be equal to the bypass correction calculated for the mounting RPTR (resp. RPTL) (all things being also equal)

Step [H]

This step aims at taking into account the **reflection loss in the silencer**, in order to predict an insertion loss.

- ***Bibliography (references) :***

[H1] -	
[H2] -	
[H3]	

- ***Comments :***

The reflection loss (**Dr** in dB) is basically computed at frequency steps of 1/21 octave (then averaged per 1/3 octave frequency band).

- **general case:** no influence of the speed of the airflow is taken into account for the computation

Model	**MUL** (*)	ZER
Reflection loss	as above (higher modes integrated)	no reflection

* No influence of a series cloth is taken into account for the computation, no influence of a series perforated protection is taken into account for the computation. The data pool used for **Dr** is related to splitters with a thickness 2d=0.1 or 0.2 or 0.3 m, filled with 1 porous medium with a flow resistivity **σx1** = **σy1** from 9 to 15 kNsm-4 (an extrapolation of **Dr** with a different thickness has been used). At the time of the present user's manual the conditions of the measurement of the data pool ([H2],[H3]) are not known with accuracy, especially the higher modes propagating in the duct in relation with the characteristics of the testing facility mentioned in [H2] (with a front section from 0.5m*0.5m to 1.3m*0.5m). For those reasons, the value obtained by the means of the unique model MUL has to be considered as a typical estimation of the reflection loss for a duct of dimensions comparable to testing facility mentioned in [H2] when no accurate information is available regarding the higher order modes (this is often the case).

- **particular cases:**

- *for the mounting R''*, the reflection loss is supposed (in all cases) to be equal to the reflection loss calculated for the mounting R (all things being also equal)

- *for the mounting C1,C2*, the reflection loss is supposed to be equal to the reflection loss calculated for the mounting R under the condition of an equal speed in the airways (all things being also equal) in case of **A=Af** (cf. § **1.1)**

- *for the mountings Q and C0*, no reflection loss has to be taken into account since **A=Af* < Af** for the present revision of the software

- *for the mounting RPTR'' (resp. RPTL'')*, the reflection loss is supposed (in all cases) to be equal to the reflection loss calculated for the mounting RPTR (resp. RPTL) (all things being also equal)

Step [I]

This step aims at taking into account the **self noise of the silencer (noise produced by the airflow).**

For dissipative silencers

- ***Bibliography (references) :***

[I1]	
[I2]	
[I3]	
[I4]	
[I5]	

[I6]	
[I7]	
[I8]	
[I9] -	
[I10]	
[I11] -	

- ***Comments:*** the self noise (acoustic power of flow noise **Lw** in dB ref 1E-12W) is basically computed at frequency steps of 1/1 octave.

  - ***for the mountings of the worksheet CODIS1*** *(R, R'', C1,C2)*, the determination of the self noise is done according various models as shown in the tables below:

model	DN1	DN2	NF1	NF2	2081A
source	[I1]	[I1]	[I2]	[I2] (*)	[I3] (**) (***)

model	**2081B**	2081R	2081C1	MUN	VER
source	[I4] (**)(***)	[I5] (**)(***)	[I5] (**)(***)	[I8] (***)	[I9] (***)

(*) B (dB) and δ (m) are input data (**) with an additional correction for temperature
(***) with an additional correction for pressure

Note: for the mounting C1,C2, the self noise is supposed to be equal to the self noise calculated for the mounting R, R' under the condition of an equal speed in the airways (all things being also equal). Furthermore a complementary model (2081C1) applies (according [I5] for the mounting C1only (not for other mountings indeed), and with A = Af* <Af (see § **1.1**) and see comments above (**)(***)

  - ***for the mountings of the worksheet CODIS2*** *(Q, C0)*, the determination of the self noise is done according various models as shown in the tables below:

model	**2081B**	3733A1	3733A2	3733B
source	[I4] (**)(***)	[I6] (**)(***)	[I6] (**)(***)	[I7] (**)(***)

  - for the models 2081 and 3733, a spectral correction is used according various models as shown in the tables below:

model	2081	**FRO**	3733
source	[I5]	[I11]	[I7]

Warning: at the time of the writing of this manual, all the consequences of the choice of one or the other model are not known with accuracy. The choice of the model can be done by the user allowing tests and feed-back.

For resonators

- ***Bibliography (references) :***

[I12] -	

- ***Comments:*** the self noise (acoustic power of flow noise **Lw** in dB ref 1E-12W) is basically computed at frequency steps of 1/1 octave.

  - ***for the mountings RPTR, RPTR'', RPTL, RPTL''***, the determination of the self noise is done according various models as shown in the tables below:

model	FRO
source	[I12]

  - for the model FRO, a spectral correction is used according various models as shown in the tables below:

model	2081	FRO	3733
source	[I5]	[I11]	[I7]

Step [J]

This step aims at calculating the **insertion loss without taking into account the self noise.**

- ***Bibliography (references) :***

[J1] -	

- ***Comments :***

The insertion loss without taking into account the self noise (**Di'** in dB) is computed at frequency steps of 1/3 octave (then calculated per 1/1 octave frequency band for a reference acoustic power spectrum **Lw0** in dB ref 1E-12W).

Di' = Da * L + Dk + Dr

Step [K]

This step aims at calculating the **insertion loss of the silencer including its self noise**.

- ***Bibliography (references) :***

[K1] -	

- ***Comments :***

The sound power level with silencer including self noise (**Lw1** in dB ref 1E-12W) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

Lw1 = 10 * log [10^ (0.1 * (Lw0 – Di')) + 10^ (0.1 * Lw)]

Lw being the self noise (acoustic power of flow noise in dB ref 1E-12W)

The insertion loss taking into account the self noise (**Di** in dB) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

Di = Lw0 – Lw1

In case of rectangular silencers, the obtained results are comparable with the standardized measurement: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units- Insertion loss, flow noise and total pressure loss (2004).

Step [L]

For resonators with pine tree splitters (only), this step (complementary, to be added between step [E] and step [F]) aims at the computation of the admittance in the plane of the outlet side of (the neck of) the chamber

- ***Bibliography (references) :***

[L1] -	
[L2]	

- ***Comments :***

The software allows the prediction of performance of silencers with chambers containing absorbing material located either at the Rear (mounting RPTR, RPTR'') or at Lateral (mountings RPTL, RPTL'').

The determination of the propagation loss is done (depending on the choice of the user) for the following cases,

σx1/σy1=∞ (absorber locally reacting), depending on **dlocal** and **hlocal** for mountings RPTR, RPTR''**(**resp. **dlocal and Hslocal** for mountings RPTL, RPTL''**)**
σx1/σy1=1 (absorber bulk reacting), depending on **dbulk** and **hbulk** for mountings RPTR, RPTR''**(**resp. **dbulkl and Hsbulk** for mountings RPTL, RPTL''**)**

For high frequency, a correction (HF correction) can be applied depending on the choice of the user (see [L1], [L2])

<u>Aerodynamics:</u>

- **Steps of the computation**

Step [α]

All computations have been gathered in this single step for the sake of simplicity (this step aims at computing the **total pressure loss** due to the silencer).

○ ***<u>Bibliography (references) :</u>***

[α1]	
[α2] -	
[α3]	
[α4]	
[α5]	
[α6]	
[α7]	
[α8]	

○ ***<u>Comments :</u>***

The total pressure loss due to the silencer is computed with the hypothesis of a uniform air flow (supposed to not be rotational), taking into account the aerodynamics type upstream and downstream (*):

Aerodynamics type downstream	R	C
*mountings R, R'', C1, C2, RPTR, RPTR'', RPTL, RPTL'' only *)*	Rectangular	1/2 Circle
		1/2 Circle for central splitters, 1/4 Circle for extreme inner lagging
		1/4 Circle for extreme inner lagging

Aerodynamics type downstream	R	C	P
*mountings R, R'', C1, C2, RPTR, RPTR'', RPTL, RPTL'' only *)*	Rectangular	1/2 Circle	Profiled according sketch, the dotted line showing either a symmetry plane or an impervious rigid back (see fig.1.13)
		1/2 Circle for central splitters, 1/4 Circle for extreme inner lagging	
		1/4 Circle for extreme inner lagging	

**for mountings Q and C0:* A=Af* < Af for the present revision of the software

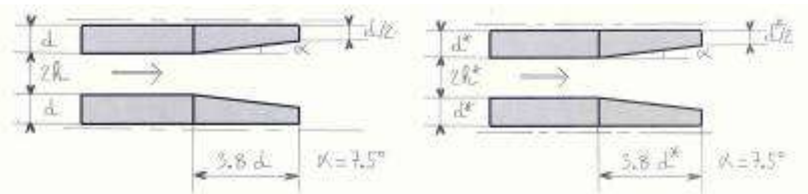


Fig.1.13

✓ ***for the mountings of the worksheet CODIS1*** *(R, R'', C1,C2)*, the determination of the total pressure loss is done is done according various models as shown in the tables below:

Model	FRO	MEC	2081C1	**<u>BER</u>**	ISO
source	[α1]	[α2]	[α6]	[α3]	[α4] [α7]

- *for the mounting R*, the total pressure loss is supposed (in all cases) to be sufficiently close to the total pressure loss calculated for the mounting R'' (all things being also equal).

- *for the mounting C1,C2*, the total pressure loss is supposed to be equal to the total pressure loss calculated for the mounting R under the condition of an equal speed in the airways (all things being also equal). Furthermore a complementary model (2081C1) applies for mounting C1 only (not for other mountings indeed), (according [α6] for the mounting C1 with **A=Af*<A**: see § **1.1**).

- ✓ ***for the mountings of the worksheet CODIS2*** *(Q, CO)*, the determination of the total pressure loss is done is done according various models as shown in the tables below:

Model	IDE
source	[α5]

- ✓ *for the mountings Q, C0*, the determination of the total pressure loss is done (A=Af* < Af for the present revision of the software) .

- ✓ ***for the mountings RPTR, RPTR'', RPTL, RPTL''***, the determination of the total pressure loss is done is done according various models as shown in the tables below:

Model	IDE
source	[α8]

- *for the mounting RPTR (resp. RPTL)*, the total pressure loss is supposed (in all cases) to be sufficiently close to the total pressure loss calculated for the mounting RPTR'' (resp. RPTL'') (all things being also equal).

In case of rectangular silencers, the obtained results are comparable with the standardized measurement: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units- Insertion loss, flow noise and total pressure loss.

*a safety factor has to be used (by the user) for taking into account the inhomogeneity of the inflow (see [α2],[α5]) leading to predictions lower than on-site values

1. 3: How to use SILDIS

Operating conditions / security level / safety

See corresponding § in the chapter **General considerations**

For safety reasons, some cells of the original file provided to the user (as mentioned in the table below) for which input data are foreseen to be entered by the user are pre-filled with the value "1/0", among the yellow cells for which the color orange is used (*).

Worksheet	Cells
[in COALA]	E13, J37
[in COSIL]	D25, BD25, D37, D43, D44, D45
[in-out COPPA]	X53, X54 (**)

* something like that

** attention has to be paid to the fact that the considered sheet is not included in the worksheets listed below

Worksheets

Regarding the COmputation of DIssipative Silencers, the software SILDIS is configurated in order to allow the user to access to 4 worksheets being linked as shown in fig.1.14 (the overview of the worksheets being shown in table below).

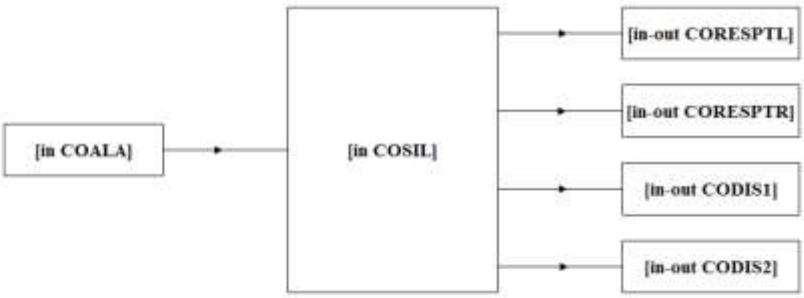


Fig. 1.14

Note: a partly common background is required for several steps of the computation schemes of different acoustic components (insertion loss of a silencer, absorption coefficient / sound reduction index of a plane partition, sound reduction index of a duct wall...). For this reason worksheets [in COALA] and [in COSIL] are distinct due to the existence of other calculations (by the means of SILDIS) using the routine COALA (COmputation of Acoustic LAyers) but not using the routine COSIL (COmputation of SILencers). For this reason also, concerning the worksheet [in COALA]:

- a complementary set (set 0) and a rear atmosphere are displayed: they are none of interest for the COmputation of DIssipative Silencers, they are none of interest for the COmputation of REsonant Silencers with Pine Tree splitters (only the case of an impervious rigid back at the rear of set1 applies for the COmputation of SILencers)
- data concerning series thin plates are displayed: they are none of interest for the COmputation of DIssipative Silencers, they are none of interest for the COmputation of REsonant Silencers with Pine Tree splitters (not taken into account whatever the input data concerning thin plates are in worksheet in [COALA])

Worksheet	Suitable for mountings	Input data	Results
[in COALA]	all	for sets, for reference spectrum	--
[in COSIL]	all	particular conditions for the design of the silencer	--
[in-out CODIS1]	R, R'', C1, C2	condition of propagation (of sound)	indicators of performance (acoustics & Aerodynamics)
[in-out CODIS2]	Q, C0		
[in-out COREPTR]	RPTR, RPTR''		
[in-out CORESPTL]	RPTL, RPTL''		

Input data, alerts and results: the key points

The best use of the software requires the knowledge of some key points in relation with:

- the **input data**

  See corresponding § in the chapter **General considerations**

  As far as porous media, series cloths and series perforated protections are concerned, specific data bases (libraries) (will) allow the design to be made with in-built engineering data (constants) referred to as "Usual" in the worksheets of the software. Warning: some properties of the presently referenced materials still not have been checked by reliable sources. See also report [PhRXX-015] Collection of soundproofing constructions systems: a companion to "User's manual for the software SILDIS"

  - **data base (library) for porous media**
    - ✓ contents of the library: **21 possible references of material layers**
  - **data base (library) for series cloths**
    - ✓ contents of the library: **21 possible references of material layers**

    Note: the cloth referenced RESISTAIR can be used (with an appropriate value for the flow resistance) for the simulation of losses of a thin plate (for example at normal incidence: due to the conditions of mounting)
  - **data base (library) for series perforated protections**
    - ✓ contents of the library: **21 possible references of material layers**

- some **alerts** in case of input data involving a warning of the user
- the place where (and the way) some **results** are presented

Those key points are reviewed worksheet per worksheet hereafter: the cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA]

- ***Input data :***

<table>
<tr><th>Item</th><th>Cell for input</th><th>Foreseen action</th><th colspan="2">Comment</th></tr>
<tr><td>Language</td><td>C1</td><td>for English input E, for French input F</td><td colspan="2"></td></tr>
<tr><td>Date</td><td>B3</td><td>Modification of the displayed date</td><td colspan="2"></td></tr>
<tr><td>Project</td><td>E3</td><td>Input a string</td><td colspan="2"></td></tr>
<tr><td>Title</td><td>M3</td><td>Input a string</td><td colspan="2"></td></tr>
<tr><td>Temperature</td><td>D6</td><td>Input a real number</td><td colspan="2">common value applicable to the fluid, to porous media, to series cloths, to perforated protection</td></tr>
<tr><td>Pressure</td><td>D7</td><td>Input a real positive number</td><td colspan="2">common value applicable to the fluid, to porous media, to series cloths, to perforated protection</td></tr>
<tr><td>Maximum set index imax</td><td>E13</td><td>Input an integer from 0 to 4</td><td rowspan="9">imax is the maximum set index taken into account for the computation, despite the status of the selection of the parameters related to sets with an index i> imax</td><td></td></tr>
<tr><td>Reference</td><td>G18 to K18</td><td>Select a material (in the proposed list) for each layer of interest</td><td>for CODIS only: a possible inhomogeneity in directions parallel to and perpendicular to its surface (i.e. different properties - depending on the used model - in directions x and y) is considered for the porous medium of set 1 (porous media of sets 2 to 4 being considered homogeneous)</td></tr>
<tr><td>Thickness</td><td>G37 to J37</td><td>Input a real positive number</td><td></td></tr>
<tr><td>Reference</td><td>G45 to J45</td><td>Select a reference of element (material in the proposed list) for each layer of interest</td><td></td></tr>
<tr><td>Incorporation of the series perforated protection (0/1)</td><td>G57 to J57</td><td>For NO press 0, for YES press 1</td><td></td></tr>
<tr><td>Thickness</td><td>G58 to J58</td><td>Input a real positive number</td><td>taken into account for the computation as a non zero value only if 1 in cell just above</td></tr>
<tr><td>Reference</td><td>T18 to W18</td><td>Select a reference of element (material in the proposed list) for each layer of interest</td><td></td></tr>
<tr><td>Incorporation of the series cloths (0/1)</td><td>T23 to W23</td><td>For NO input 0, for YES input 1</td><td></td></tr>
<tr><td>Thickness</td><td>T24 to W24</td><td>Input a real positive number</td><td>taken into account for the computation as a non zero value only if 1 in cell just above</td></tr>
<tr><td>Lw0 only known per 1/1 octave frequency band (0/1)</td><td>R62</td><td>For NO input 0, for YES input 1</td><td colspan="2">In case of input “0”: the input data of the table below are not applicable, the next table only must be filled</td></tr>
<tr><td>Lw0</td><td>B65 to K65</td><td>Input a real positive number as requested for a 1/1 octave band sound power level</td><td colspan="2"></td></tr>
<tr><td>Lw0</td><td>B70 to P70
B73 to P73</td><td>Input a real positive number as requested for a 1/1 octave band sound power level</td><td colspan="2">In case of Lw0 only known per 1/1 octave frequency band, default values are foreseen such as
Lw0 1/3 oct = Lw0 1/1 oct - 4.8 (dB)</td></tr>
</table>

- ***Comments*** :

    - data of the second table (below) are not taken into account for the design of dissipative silencers (useful for other calculations in relation with the COmputation of Acoustic LAyers)

Item	Cell for input	Foreseen action	Comment
Rear atmosphere ? (0/1)	O8	For NO input 0, for YES input 1	not taken into account for CODIS
Reference	T31 to W31	Select a reference of element (material in the proposed list) for each layer of interest	
(1/2)	Y31	Select a number (in the proposed list)	select 1 (resp. 2) to get for set 0 the same plate as for set 1 (resp. set 2)
Model of losses	T36 to W36	Select a model (in the proposed list)	
Model of effective critical frequency	T37 to W37	Select a model (in the proposed list)	
Number of identical plates	T38 to X38	Input a real positive number	
Thickness	T39 to W39	Input a real positive number	taken into account for the computation as a non zero value only if a non zero value in cell just above

Note: temperature (resp. pressure) of cell D6 (resp. D7) also apply to thin plates

- data of the third table (below) are not modifiable by the user despite the displayed color of the cell

Item	Cell for input	Foreseen action	Comment
For (test) room conditions below: temperature	S48	Input a real number	common value applicable to the fluid, to porous media, to series cloths, to perforated protection
For (test) room conditions below: pressure	S49	Input a real positive number	common value applicable to the fluid, to porous media, to series cloths, to perforated protection

Worksheet [in COSIL]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment	
d* (m)	BD8	Input a positive real	For the COmputation of REsonant Silencers with Pine Tree splitters only	
Θ (°)	BD10	Input a positive real		
Ss (m)	BD12	Input a positive real		
Sa (m)	BD13	Input a positive real		
HF correction (0/1)	BD15	For NO input 0, for YES input 1		
Limit set index **ilim**	D18	Input an integer from 1 to **imax**	**imax**- ξ ≤ **ilim** ≤ **imax** (ξ being the total number of cloths and perforated protections accounted as porous media)	
To get h/(d+h) =	G24	Input a positive real	If a particular value of h/(d+h) is wished	For the COmputation of DIssipative Silencers only (no compulsory input)data
To get d/h =	H24	Input a positive real	If a particular value of d/h is wished	
To get (d/h)local =	J24	Input a positive real <1	If a particular value of (d/h)local is wished	
To get (d/h)bulk =	K24	Input a positive real <1	If a particular value of (d/h)bulk is wished	
Mounting R'' to get N'' =	O24	Input a positive real	If a particular value of N'' is wished (given B)	
Mounting C0 ½ to get D0 ½ = (m)	Q24	Input a positive real	If a particular value of D0 ½ is wished	
Mounting C1to get D1 = (m)	T24	Input a positive real	If a particular value of D1 is wished	
Mounting C1to get D1-2d = (m)	U24	Input a positive real	If a particular value of D1-2d is wished	
Mounting C1 ½ to get D1 ½ = (m)	W24	Input a positive real	If a particular value of D1 ½ is wished	
Mounting C2 to get D2 = (m)	Z24	Input a positive real	If a particular value of D2 is wished	
Mounting C2 to get D2-2d = (m)	AA24	Input a positive real	If a particular value of D2-2d is wished	
Mounting C2 ½ to get D2 ½ = (m)	AC24	Input a positive real	If a particular value of D2 ½ is wished	
Mounting C3 to get D3 = (m)	AF24	Input a positive real	If a particular value of D3 is wished	
Mounting C3 to get D3-2d = (m)	AG24	Input a positive real	If a particular value of D3-2d is wished	
Mounting C3 ½ to get D3 ½ = (m)	AI24	Input a positive real	If a particular value of D3 ½ is wished	
Mounting CR to get D = (m)	AL24	Input a positive real	If a particular value of D is wished	
For D (m) =	AM24			
Mounting Q to get Q = (m)	AQ24	Input a positive real	If a particular value of Q is wished	
Mounting Q to get Q-2d = (m)	AR24	Input a positive real	If a particular value of Q-2d is wished	
Mounting C0 to get D0 = (m)	AU24	Input a positive real	If a particular value of D0 is wished	
Mounting C0 to get D0-2d = (m)	AV24	Input a positive real	If a particular value of D0-2d is wished	
Mounting C0 to get d/a = (m)	AW24	Input a positive real	If a particular value of a/h is wished	
Mounting C0 to get (d/a)bulk = (m)	AX24	Input a positive real	If a particular value of (a/h)bulk is wished	
Mounting RPT'' to get N''* =	BH24	Input a positive real	If a particular value of N''* is wished (given B)	No compulsory input data
Half airway h (m)	D25	Input a positive real	If a particular value of h/(d+h) resp. (d/h), (d/h)local…is wished then input the value given in G25 (resp. H25, J25…)	
Half airway h* (m)	BD25	Input a positive real	If a particular value of N''* is wished then input	For the COmputation of REsonant Silencers with

			the value given in AQ25	Pine Tree splitters only
Mass flow rate	D37	Input a real	A positive value is related to a direction of airflow equal to the direction of propagation of sound, a negative value is related to a direction of airflow opposite to the direction of propagation of sound	
Mounting R’’ to get N’’ =	O42	Input a positive real	If a particular value of N’’ is wished (given h)	For the COmputation of DIssipative Silencers only (no compulsory input data)
Mounting CR to get Ncr =	AL42	Input a positive real	If a particular value of Ncr is wished (given h)	
Mounting RPT’’ to get N’’* =	BHQ42	Input a positive real	If a particular value of N’’* is wished (given h*)	For the COmputation of REsonant Silencers with Pine Tree splitters only No compulsory input data
Width B (m)	D43	Input a positive real	If a particular value of N’’ (resp. N’’*) is wished then input the value given in O43 (resp. AQ43). If the extrapolation from mounting R to a particular mounting is wished then input the value given in R43 (resp. U43, AA43…)	
Height H (m)	D44	Input a positive real	If the extrapolation to a particular mounting is wished then input the value given in R44 (resp. U44, AA44…)	
Length L (m)	D45	Input a positive real	Without aerodynamics extremities	
Model of reflection loss	G47	Select a model (in the proposed list)	Not applicable for mountings Q, C0	
Model of by-pass correction	E51 to G51	Select a model (in the proposed list)		
Aerodynamics upstream	D54	Select a model (in the proposed list)	Not applicable for mountings Q, C0	
Aerodynamics downstream	D55	Select a model (in the proposed list)	Not applicable for mountings Q, C0	
The direction of flow is the direction of the foot of the pine tree when the branches shape of the splitters is considered (0/1)	BH59	For NO input 0, for YES input 1	For the COmputation of REsonant Silencers with Pine Tree splitters only	
Roughness of lining Δ (m)	AW61	Input a positive real	For the COmputation of DIssipative Silencers with mountings Q, C0 only	
Model of total pressure loss	V63	Select a model (in the proposed list)	For the COmputation of DIssipative Silencers with mountings R, R’’, C0 ½, C1, C1 ½, C2, C2 ½, C3, C3 ½, CR only	
Model of total pressure loss	BH63	Select a model (in the proposed list)	For the COmputation of REsonant Silencers with Pine Tree splitters only	
For model NF2 only B (dB)	E64	Input a positive real	For the COmputation of DIssipative Silencers with mountings R, R’’, C0 ½, C1, C1 ½, C2, C2 ½, C3, C3 ½, CR only	
For model NF2 only δ (m)	G64	Input a positive real		
For all models 2081,3733, FRO only spectral correction model	G65	Select a model (in the proposed list)	Used for the interpolation of a ponderation curve (generally of secondary importance)	
Model for the flow acoustic power	V65,AW65	Select a model (in the proposed list)	For the COmputation of DIssipative Silencers only	

- ***Comments :***

Item	Cell	Foreseen action	Comment
STOP ilim>imax	D19, E19	--	In case of such an alert, the input value for **ilim** has to be changed, such as **ilim ≤ imax (*)**
not applicable	G48	--	In case of such an alert, the input value for the model of reflection loss has to be changed

*the use of results obtained with worksheets including at least 1 alert is highly discouraged

Worksheets [in-out CODIS1], [in-out CODIS2], in-out CORESPTR], [in-out CORESPTL]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Condition of propagation	W182	Select a model (in the proposed list)	among the possible conditions of propagation in porous medium of set 1 (for the COmputation of DIssipative Silencers **σx1/σy1**=∞, **σx1/σy1**=1, **σx1/σy1**=var.; for the COmputation of REsonant Silencers with Pine Tree splitters only **σx1/σy1**=∞, **σx1/σy1**=1)

- ***Comments :***

Item	Cell	Foreseen action	Comment
STOP	E14	--	In case of such an alert, the input value for **ilim** has to be changed, such as **ilim ≤ imax (*)**
r < rmini: σx1/σy1 ≠ ∞ discouraged	R50, V97	--	In case of such an alert, the flow resistance of the porous medium of set 1 has to be increased if results for non local absorber are wished (*)

*the use of results obtained with worksheets including at least 1 alert is highly discouraged

- ***Main displays of the results :***

  - **total pressure loss**: **see lines 98 to 100**

    Note: the following equation is considered for the definition of total pressure loss coefficients **ζf, ζf*, ζp**:

    $$\Delta pt = \zeta p \cdot 0.5 \cdot \rho \cdot (Vp)^2 = \zeta f \cdot 0.5 \cdot \rho \cdot (Vf)^2 = \zeta f^* \cdot 0.5 \cdot \rho \cdot (Vf^*)^2$$

    Δpt: total pressure loss (Pa)
    ρ: density of fluid (kgm-3)
    Vp: speed in the area Ap (ms-1)
    Vf: speed in the area Sf (ms-1)
    Vf*: speed in the area Sf (ms-1)

- **insertion loss without flow: see line 105** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.

  Note: those results are intermediate/complementary results not equal (generally speaking) to the insertion loss with flow and self noise that the user has to use as the only reliable indicator of performance of the performance of the silencer. Those results are only displayed in order to allow the evaluation of the impact of airflow - other than self noise - by the means of a comparison with results displayed line 106.

- **insertion loss with flow without flow noise (Di'): see line 106** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.

  Note 1: those results are intermediate/complementary results not equal (generally speaking) to the insertion loss with flow and self noise that the user has to use as the only reliable indicator of performance of the performance of the silencer. Those results are only displayed in order to allow the evaluation of the impact:

  - of airflow - other than self noise - by the means of a comparison with results displayed line 105
  - of flow noise by the means of a comparison with results displayed line 162

  Note 2: since the insertion loss is predicted from the sum of the longitudinal attenuation, a bypass correction and reflection loss, the results corresponding to the different terms of the sum are also displayed in order to allow the evaluation of the impact of each one (see table below).

Term of the sum	Cells for display	Notation	Comment
longitudinal attenuation	**A108 to L127**	Da.L	curve and table of results per 1/3 octave band, per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum
by pass correction	**M108 to X127**	Dk	
reflection loss	**A129 to L148**	Dr	
insertion loss without self noise	**M129 to X148**	D'i= Da.L+ Dk+ Dr	

- **self noise (acoustic power of flow noise): see line 153** per 1/1 octave frequency band and in terms of A weighted global value
- **not A-weighted acoustic power with silencer (Lw1)**: **see line 156** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.
- **A-weighted acoustic power with silencer**: **see line 157** per 1/1 octave frequency band
- **insertion loss with flow and self noise (Di)**: **see line 162** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.
- **acoustic power without silencer (Lw0) and acoustic power with silencer including self noise (Lw1) versus frequency see lines 164 to 184 columns A to F** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.
- **insertion loss with flow without self noise (Di') and insertion loss with flow and self noise (Di) versus frequency see lines 164 to 184 columns G to L** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.

1.4: Examples of computation with SILDIS

Example 1.4.1 dissipative silencer with a rectangular cross section

Envisaged application

It is wished to compute the acoustic and aerodynamic performances of a **dissipative silencer with a rectangular cross section** (width B=1200mm [1], height H=2000mm [2], length L=1500mm [3]), having rectangular edged [4] splitters of thickness 2d such as 2d-2d'1=200mm [5] with a open area ratio of 50% [6] made of one [7] homogeneous in directions parallel to and perpendicular to its surface bulk absorber [8] having the reference DEMO in the database for porous media of SILDIS [9] with [10] a cloth of thickness d'1=5/100 mm [11] having the reference DEMO in the series cloths database of SILDIS [12] without perforated protection [13]
It is foreseen to use the silencer with an air flow rate of 24.1 kg/s [14] at 20 °C [15] at a pressure of 101325 Pa [16].
It is decided to take into account a limitation of the propagation loss for L>1m [17] and to take into account the reflection loss [18].
The reference spectrum is supposed of the type "pink noise" [19] with a sound power level of 130 dB/oct [20]
It is chosen to predict the self noise of the silencer in the way described with the model referred to as 2081B [21]
It is chosen to predict the back pressure with the model referred to as FRO [22]

Input data

The input data required for the computation are listed hereafter in reference with the above data (see figures in brackets in the previous §, used as placemarks for explaining the selection below).The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA] for example 1.4.1 and for example 1.4.2a and for example 1.4.2b

Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark / comment
Temperature	D6	Input a real number	20	[15]
Pressure	D7	Input a real positive number	101325	[16]
Maximum set index **imax**	E13	Input an integer from 1 to 4	1	[7]
Reference	J18 to K18	Select a reference (material in the proposed list) for each layer of interest	DEMO	[8],[9]
Thickness	J37	Input a real positive number	0.1	[5]
Incorporation of the series perforated protections (0/1)	J57	For NO press 0, for YES press 1	0	[13]
Reference	W18	Select a material (in the proposed list) for each layer of interest	DEMO	[12]
Incorporation of the series cloths (0/1)	W23	For NO input 0, for YES input 1	1	[10]
Thickness	W24	Input a real positive number	0.00005	[11]
Lw0 only known per 1/1 octave frequency band (0/1)	R62	For NO input 0, for YES input 1	1	[20]
Lw0	B65 to K65	Input a real positive number as requested for a 1/1 octave band sound power level	130	[20]

Worksheet [in COSIL] for example 1.4.1 only

Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark
Limit set index **ilim**	D18	Input an integer from 1 to **imax**	1	[7]
h/(d+h)	G24	Input a positive real <1	0.5	[6]
Half airway	D25	Input a positive real	=G25 i.e. 0.10005	
Mass flow rate	D37	Input a real	24.1	[14]
Width B (m)	D43	Input a positive real	1.2	[1]
Height H (m)	D44	Input a positive real	2	[2]
Length L (m)	D45	Input a positive real	1.5	[3]
Model of reflection loss	G47	Select a model (in the proposed list)	MUL	[18]
Model of by-pass correction for L>1m	F51	Select a model (in the proposed list)	FRO	[17]
Aerodynamics upstream	D54	Select a model (in the proposed list)	R	[4]
Aerodynamics downstream	D55	Select a model (in the proposed list)	R	[4]
Model of total pressure loss	V63	Select a model (in the proposed list)	FRO	[22]
Model for the flow acoustic power	V65	Select a model (in the proposed list)	2081B	[21]

Worksheet [in-out CODIS1] for example 1.4.1 only

Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark
Condition of propagation	W182	Select a model (in the proposed list)	**σx1/σy1**=1	[8]

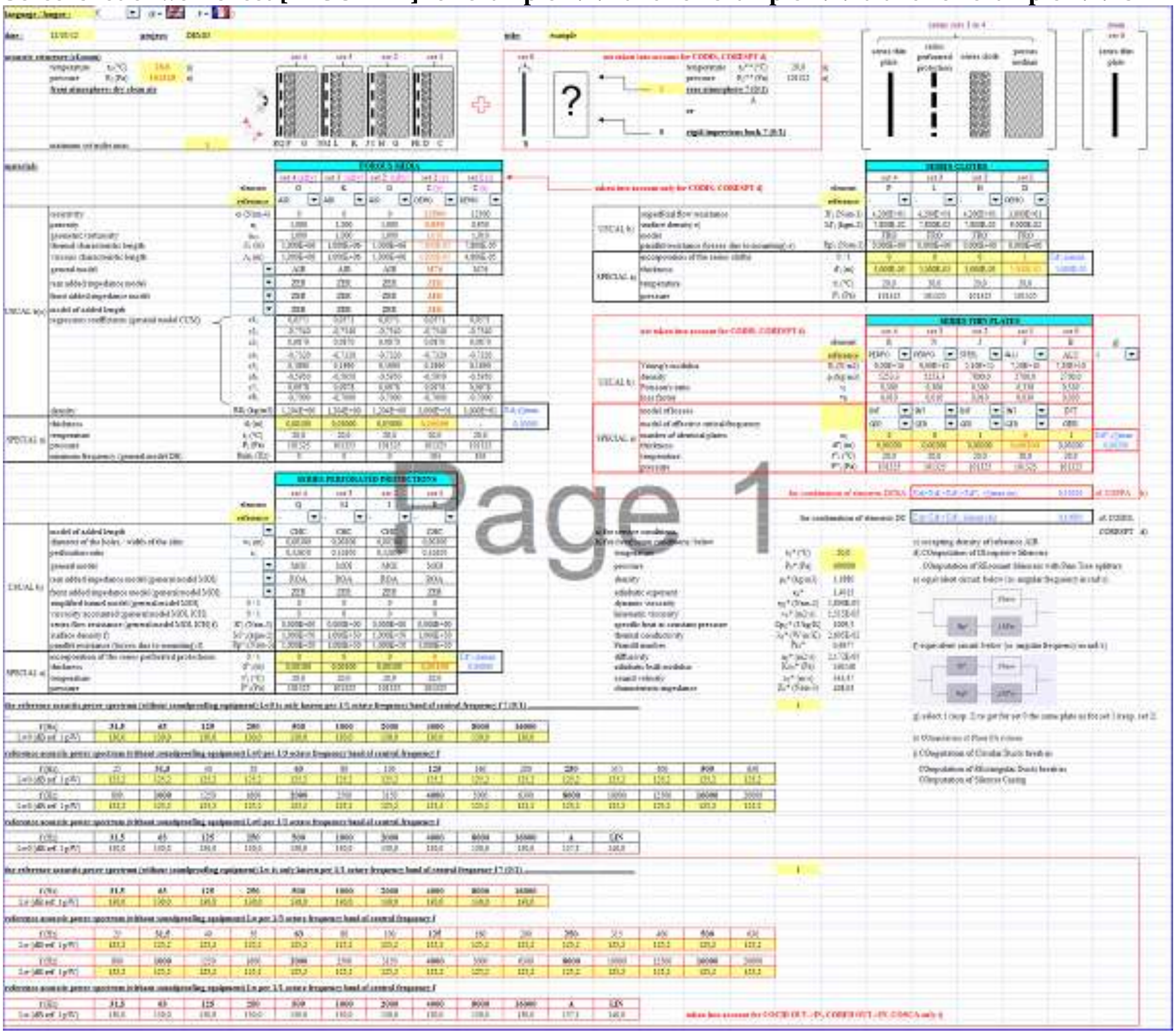
Worksheet [in-out COPPA] for example 1.4.1 and for example 1.4.2a and for example 1.4.2b

Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark
Size of the partition along the x-direction	X53	Input a positive real	1	(*)
Size of the partition along the z-direction	X54	Input a positive real	1	(*)

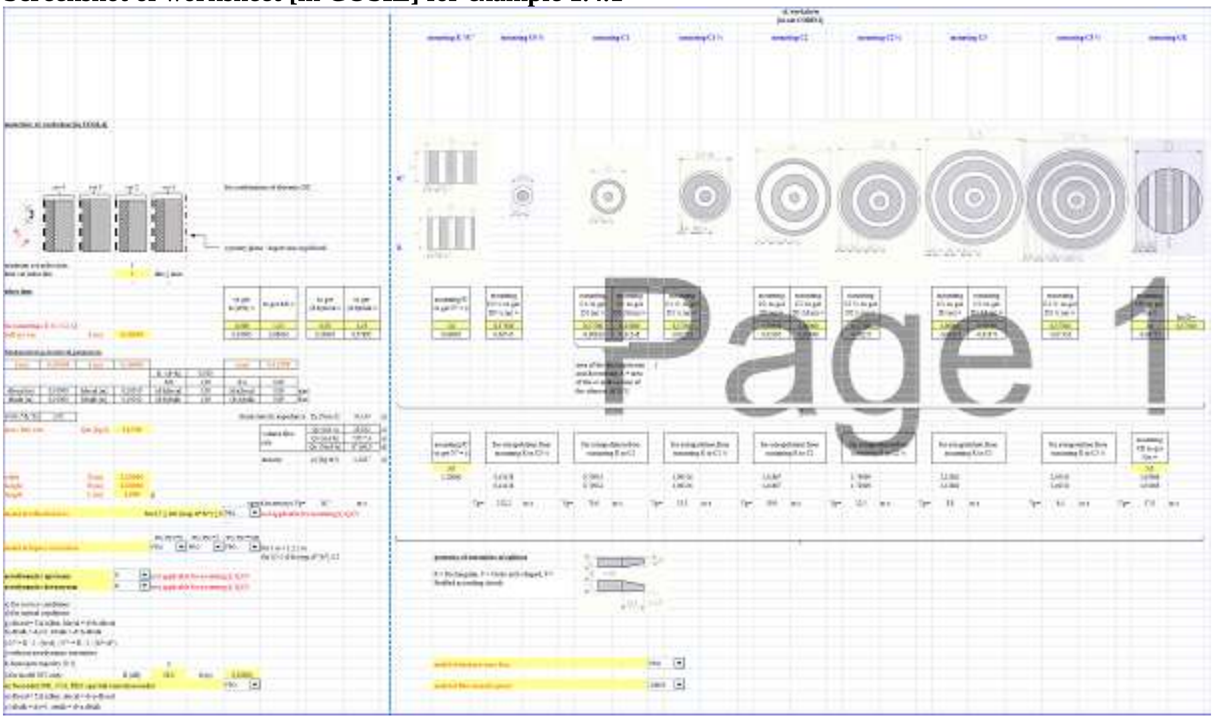
*see § **1. 3: How to use SILDIS <u>Operating conditions / security level / safety</u>**

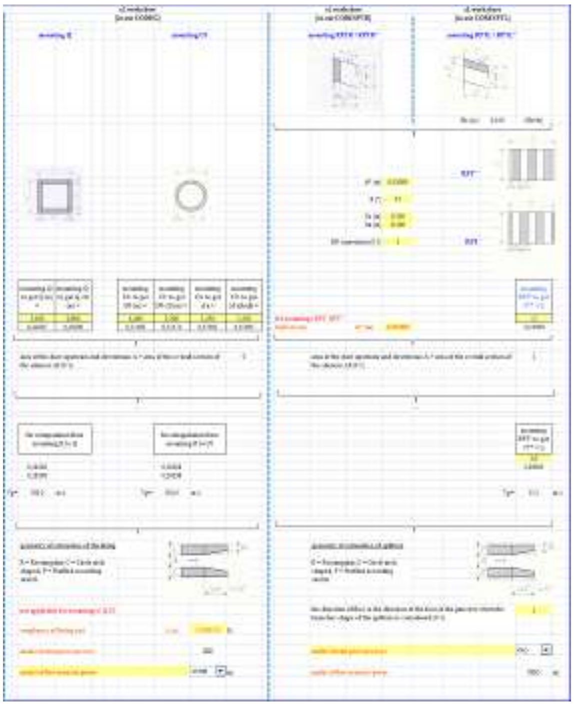
<u>Screenshots of the worksheets (for the example of computation)</u>

Screenshot of worksheet [in COALA] for example 1.4.1 and for example 1.4.2a and for example 1.4.2b

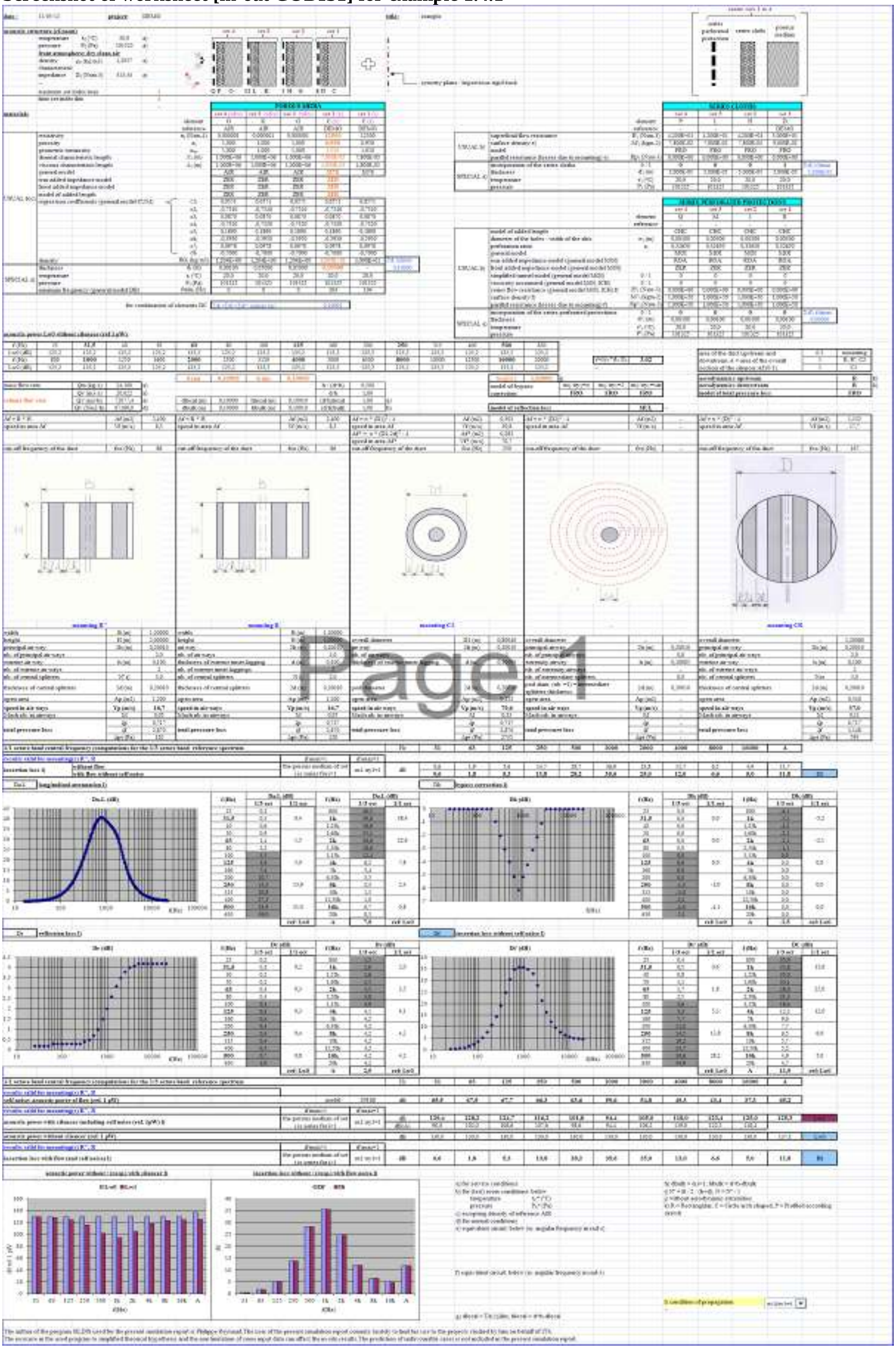


Screenshot of worksheet [in COSIL] for example 1.4.1





Screenshot of worksheet [in-out CODIS1] for example 1.4.1



Example 1.4.2a: dissipative silencer with a square cross section

Envisaged application

It is wished to compute the acoustic and aerodynamic performance of a **dissipative silencer with a square cross section**, the area of the duct upstream and downtream (above and below the silencer) being not equal to the area of the overall section of the silencer (overall width=overall height Q=1100mm [1']) but being equal to the inner width, length L=1500mm [3]), having a lining of thickness d such as d-d'1=100mm [5] made of one [7] homogeneous in directions parallel to and perpendicular to its surface bulk absorber [8] having the reference DEMO in the database for porous media of SILDIS [9] with [10] a cloth of thickness d'1=5/100 mm [11] having the reference DEMO in the series cloths database of SILDIS [12] without perforated protection [13]
It is foreseen to use the silencer with an air flow rate of 24.1 kg/s [14] at 20 °C [15] at a pressure of 101325 Pa [16].
It is decided to take into account a limitation of the propagation loss for L>1m [17].
The reference spectrum is supposed of the type "pink noise" [19] with a sound power level of 130 dB/oct [20]
It is chosen to predict the self noise of the silencer in the way described with the model referred to as 2081B [21]
A roughness of 1 mm is assumed for the lining [23])

Input data

The input data required for the computation are listed hereafter in reference with the above data (see figures in brackets in the previous §, used as placemarks for explaining the selection below).The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA] for example 1.4.2a See corresponding § for **example 1.4.1**

Worksheet [in COSIL] for example 1.4.2a only

Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark
Limit set index **ilim**	D18	Input an integer from 1 to **imax**	1	[7]
Mounting Q to get Q = (m)	AQ24	Input a positive real	1.100	[1']
Airway h (m)	D25	Input a positive real	=AQ25 i.e. 0.44995	
Mass flow rate	D37	Input a real	24.1	[14]
Width B (m)	D43	Input a positive real	=AQ43 i.e. 0.99493	
Height H (m)	D44	Input a positive real	=AQ44 i.e. 0.99493	
Length L (m)	D45	Input a positive real	1.5	[3]
Model of by-pass correction for L>1m	F51	Select a model (in the proposed list)	FRO	[17]
Roughness of lining	AW61	Input a real	0.001	[23]
Model for the flow acoustic power	AW65	Select a model (in the proposed list)	3733B	[21]

Worksheet [in-out CODIS2] for example 1.4.2a and for example 1.4.2b only

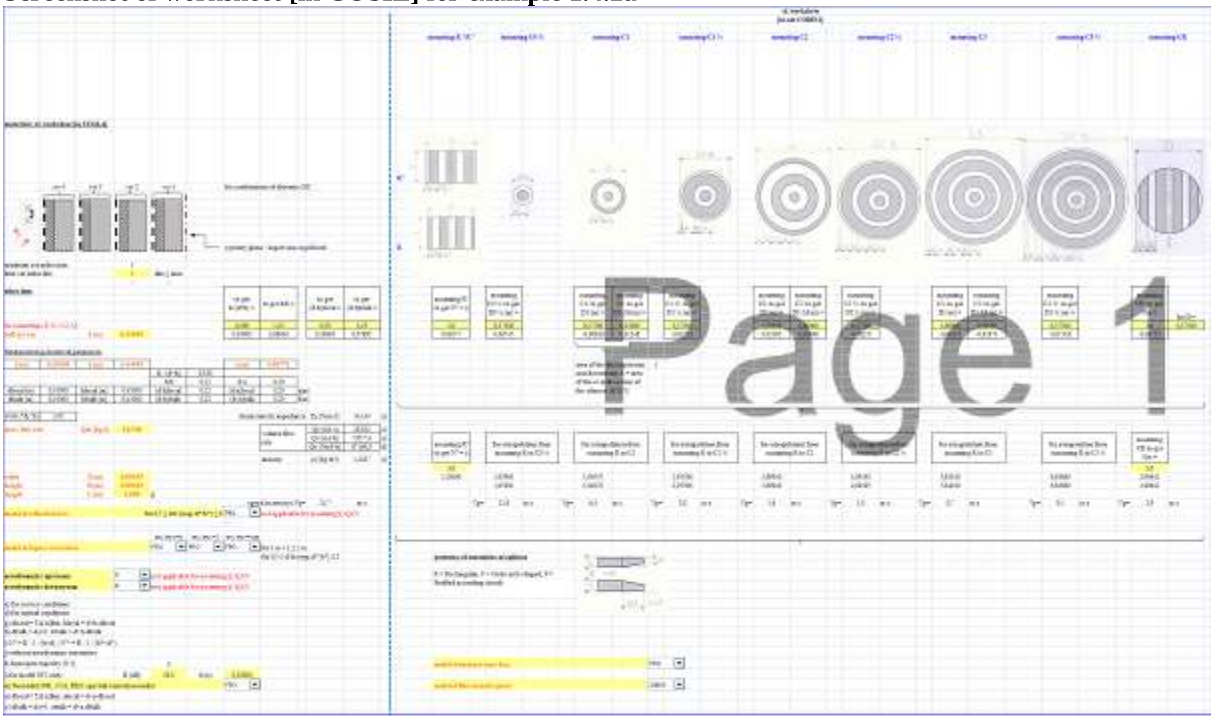
Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark
Condition of propagation	W182	Select a model (in the proposed list)	**σx1/σy1**=1	[8]

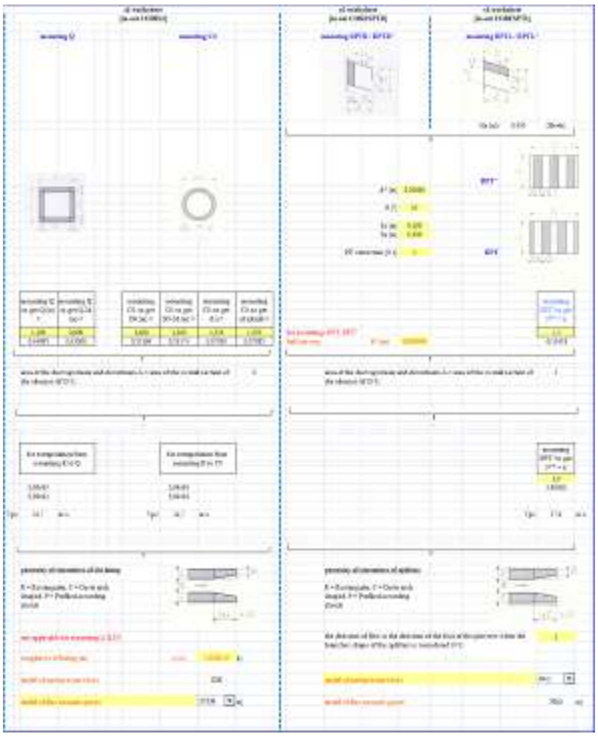
Worksheet [in-out COPPA] for example 1.4.2a See corresponding § for **example 1.4.1**

<u>Screenshots of the worksheets (for the example of computation)</u>

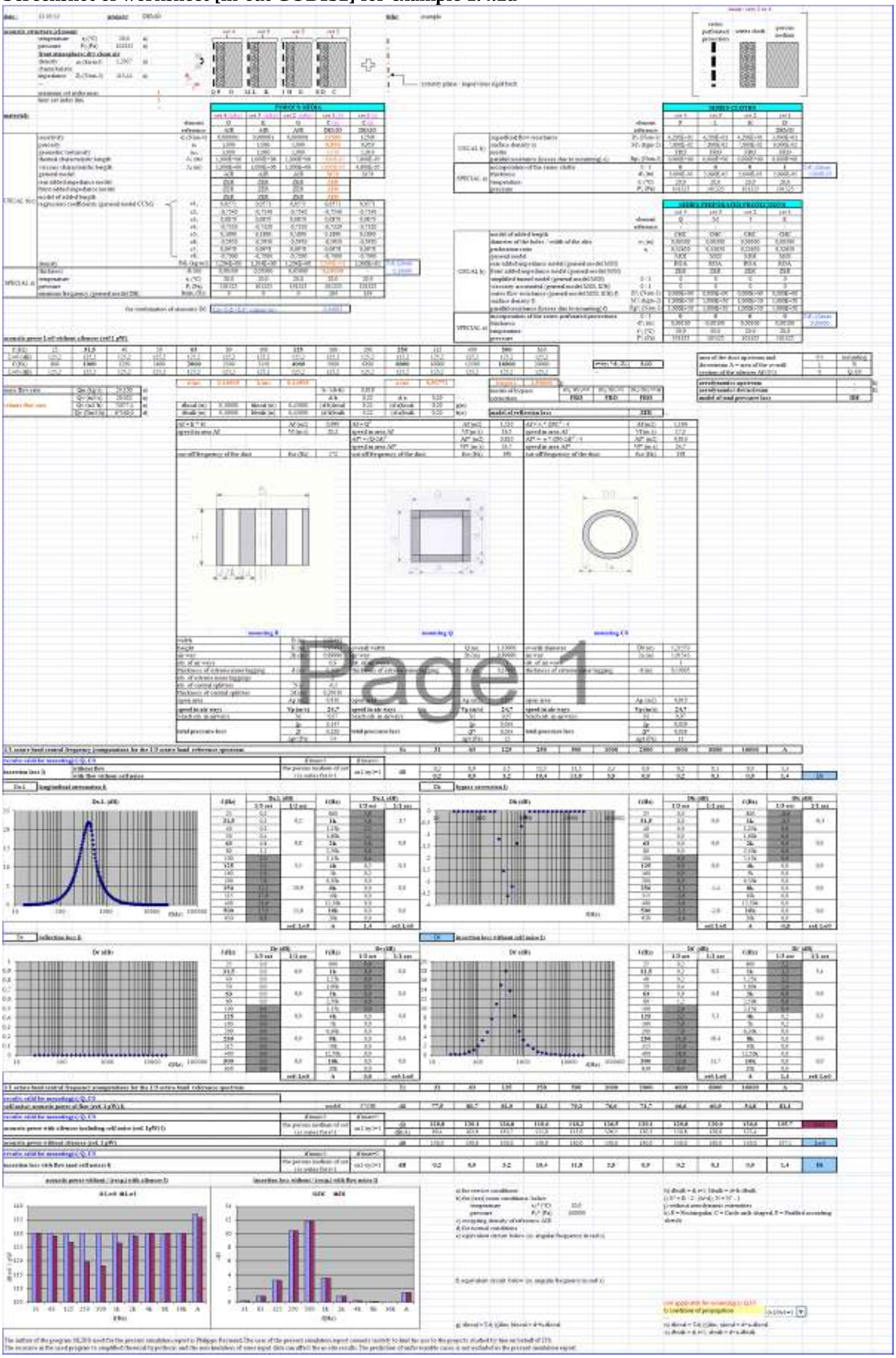
Screenshot of worksheet [in COALA] See corresponding § for **example 1.4.1**

Screenshot of worksheet [in COSIL] for example 1.4.2a





Screenshot of worksheet [in-out CODIS2] for example 1.4.2a



<u>Example 1.4.2b</u> dissipative silencer with a circular cross section

<u>Envisaged application</u>

It is wished to compute the acoustic and aerodynamic performance of a **dissipative silencer with** a **circular cross section**, the area of the duct upstream and downtream (above and below the silencer) being <u>not</u> equal to the area of the overall section of the silencer (overall diameter D0=1400mm [1’’]) but being equal to the inner diameter, length L=1500mm [3]), having a lining of thickness d such as d-d’1=100mm [5] made of one [7] homogeneous in directions parallel to and perpendicular to its surface bulk absorber [8] having the reference DEMO in the database for porous media of SILDIS [9] with [10] a cloth of thickness d’1=5/100 mm [11] having the reference DEMO in the <u>series</u> cloths database of SILDIS [12] without perforated protection [13]
It is foreseen to use the silencer with an air flow rate of 24.1 kg/s [14] at 20 °C [15] at a pressure of 101325 Pa [16].
It is decided to take into account a limitation of the propagation loss for L>1m [17].
The reference spectrum is supposed of the type “pink noise” [19] with a sound power level of 130 dB/oct [20]
It is chosen to predict the self noise of the silencer in the way described in the model referred to as 2081B [21]
A roughness of 1 mm is assumed for the lining [23])

<u>Input data</u>

The input data required for the computation are listed hereafter in reference with the above data (see figures in brackets in the previous §, used as placemarks for explaining the selection below).The input cells will be referred to thanks to their EXCEL’s coordinates (column / line) in the following part of the present user’s manual.

Worksheet [in COALA] for example 1.4.2b See corresponding § for **example 1.4.1**

Worksheet [in COSIL] for example 1.4.2b only

Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark
Limit set index **ilim**	D18	Input an integer from 1 to **imax**	1	[7]
Mounting C0 to get D0 = (m)	AU24	Input a positive real	1.4	[1’’]
Half airway h (m)	D25	Input a positive real <1	=AD25 i.e. 0.53169	
Mass flow rate	D37	Input a real	24.1	[14]
Width B (m)	D43	Input a positive real	=AV43 i.e. 1.15912	
Height H (m)	D44	Input a positive real	=AV 44 i.e. 1.15912	
Length L (m)	D45	Input a positive real	1.5	[3]
Model of by-pass correction for L>1m	F51	Select a model (in the proposed list)	FRO	[17]
Roughness of lining	AW61	Input a real	0.001	[23]
Model for the flow acoustic power	AW65	Select a model (in the proposed list)	3733B	[21]

Worksheet [in-out CODIS2] for example 1.4.2a and for example 1.4.2b only

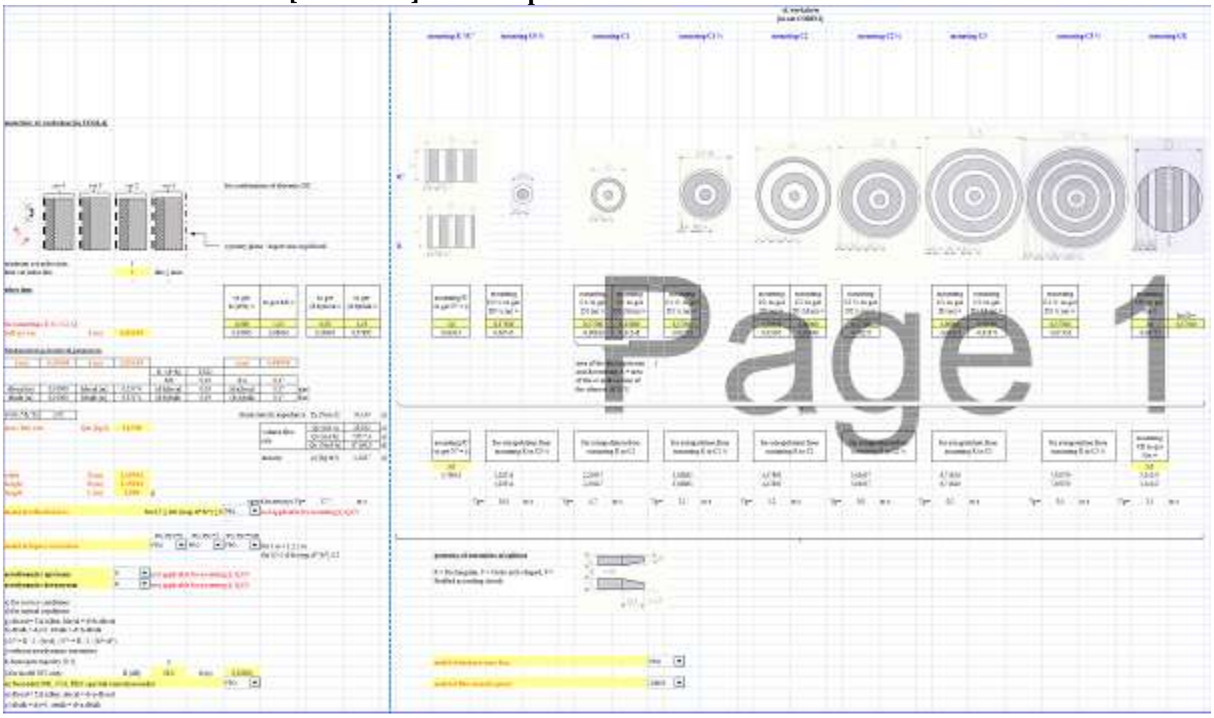
Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark
Condition of propagation	W182	Select a model (in the proposed list)	**σx1/σy1**=1	[8]

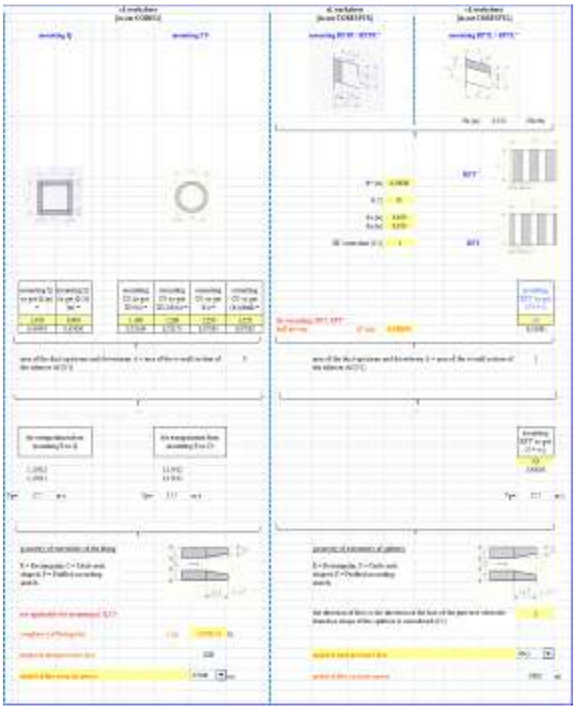
Worksheet [in-out COPPA] for example 1.4.2b See corresponding § for **example 1.4.1**

Screenshots of the worksheets (for the example of computation)

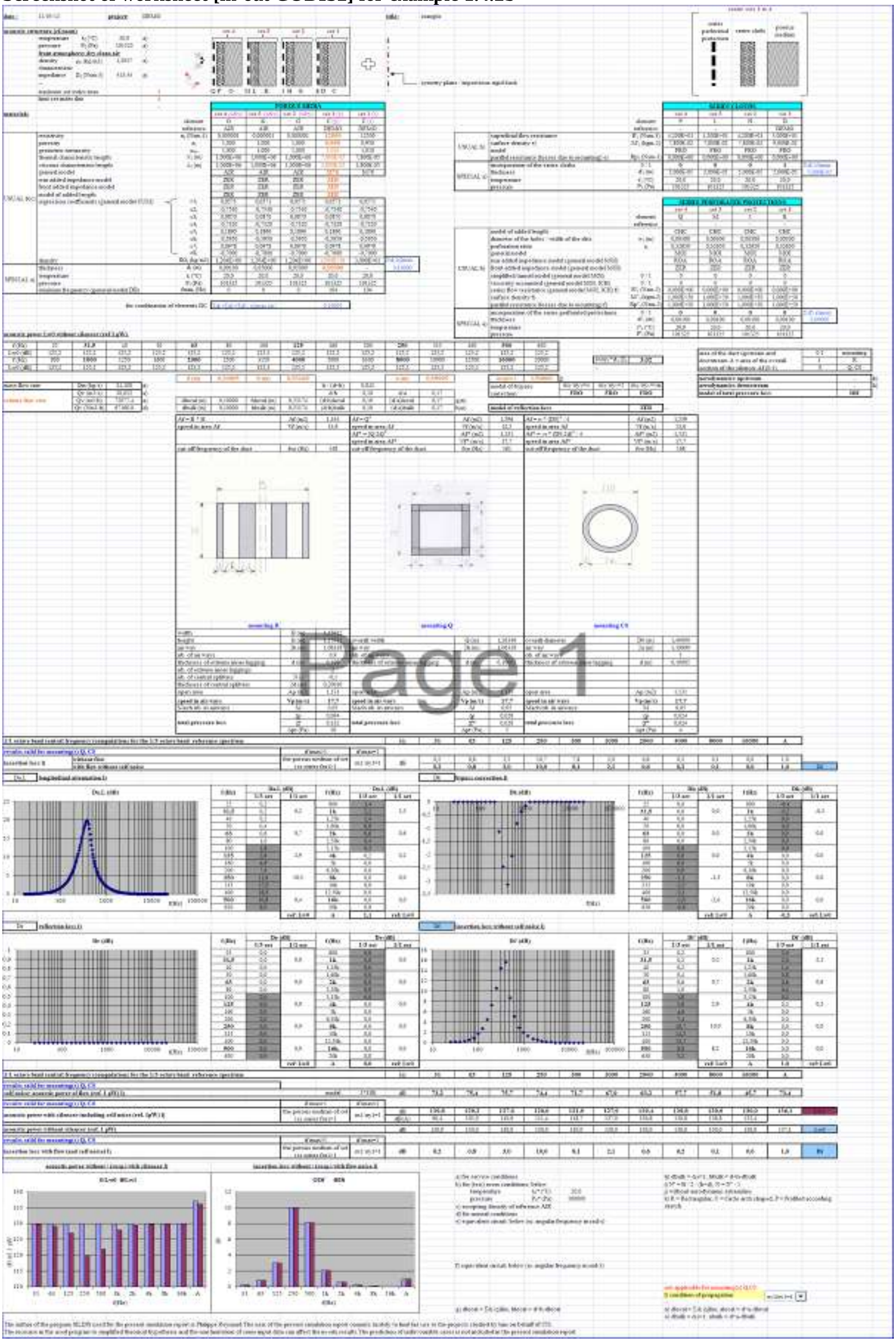
Screenshot of worksheet [in COALA] See corresponding § for **example 1.4.1**

Screenshot of worksheet [in COSIL] for example 1.4.2b





Screenshot of worksheet [in-out CODIS2] for example 1.4.2b



1.5: Illustrations of effects taken into account with SILDIS

Introduction

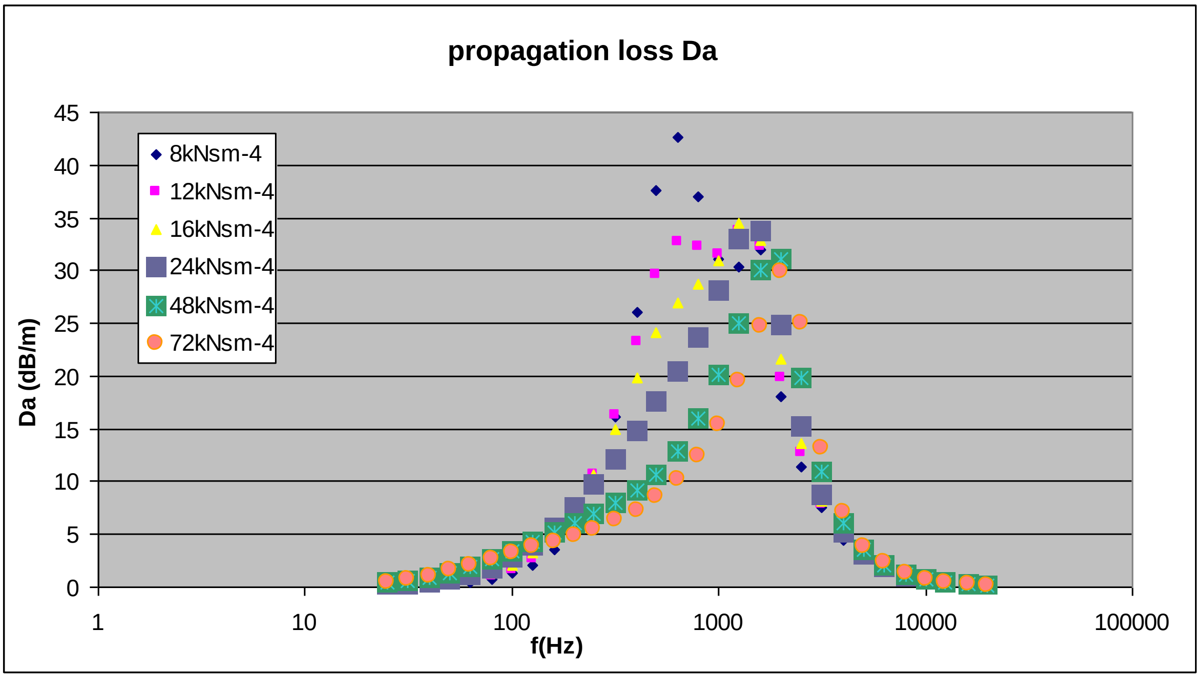
The prediction of acoustic performances of dissipative silencers with the software SILDIS is founded on a scientific and technical background as presented in § 1.2 of this user's manual, combining various knowledges in relation with physics. Some (future possible) users may not be perfectly familiar with some aspects of this background: in order to be anyway in a position of making the best use of this calculation tool, attention has to be paid by such users to some particular effects taken into account for the predictions thanks to illustrations (applying for a rectangular cross section) given in this section of the user's manual. The intention is not to give a comprehensive list of the various effects of each parameter that may (alone or coupled with others) influence the acoustic performance of a dissipative silencer, what would be very difficult to do. The goal is (thanks to examples): highlighting major key-points (considered separately) of the design of a dissipative silencer, given some known laws of the physics, some of the input data being chosen in order to be as demonstrative as possible, given the plausible field of typical engineering applications.

All the numerical results below have been obtained using the software SILDIS with some post treatment for comparisons notably (some of those results can not be obtained by the user in the presented form for a sake of simplicity of the software).

Effects of the properties of a porous medium in a non-laminated lining (illustration 1.5.1)

Imput data: a silencer is considered at (test) room pressure and temperature, with an open area ratio of 50%, the splitters having transverse solid partitions inhibiting the sound propagation along the duct axis inside the non-laminated lining consisting of a single porous medium having (at room temperature) a flow resistivity in the direction normal to the axis of the duct **σy1** varying from 8 to 72 kNsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.1m. No series cloth is considered, no series perforated protection is considered.

Illustration of one of the effects: see below the prediction of the propagation loss depending on the flow resistivity of the porous medium (see key in the graph)



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
8kNsm-4	0,1	0,1	0,2	0,3	0,5	0,8	1,3	2,1	3,5	5,9	9,8	16,2	26,0	37,6	42,6	37,0	31,1	30,3	32,0	18,1	11,4	7,6	4,4	2,8	1,7	1,1	0,7	0,4	0,3	0,2
12kNsm-4	0,1	0,2	0,3	0,4	0,7	1,1	1,7	2,7	4,3	6,8	10,7	16,3	23,2	29,6	32,7	32,2	31,6	33,7	32,2	19,9	12,7	7,8	4,7	2,9	1,8	1,1	0,7	0,4	0,3	0,2
16kNsm-4	0,1	0,2	0,4	0,6	0,9	1,4	2,1	3,3	4,9	7,3	10,6	15,0	19,8	24,1	26,9	28,7	30,9	34,5	32,8	21,6	13,6	8,1	4,9	2,9	1,8	1,1	0,7	0,4	0,3	0,2
24kNsm-4	0,2	0,3	0,5	0,8	1,2	1,8	2,8	4,0	5,6	7,6	9,8	12,2	14,8	17,6	20,4	23,7	28,1	33,0	33,7	24,9	15,2	8,8	5,2	3,1	1,9	1,1	0,7	0,4	0,3	0,2
48kNsm-4	0,4	0,6	0,9	1,3	1,9	2,6	3,4	4,3	5,2	6,1	7,0	8,0	9,2	10,7	12,9	16,0	20,1	25,0	30,0	31,1	19,9	11,0	6,1	3,5	2,1	1,2	0,8	0,5	0,3	0,2
72kNsm-4	0,5	0,8	1,1	1,6	2,1	2,6	3,2	3,8	4,3	4,9	5,5	6,3	7,3	8,6	10,2	12,4	15,4	19,5	24,7	29,9	25,0	13,2	7,1	3,9	2,3	1,3	0,8	0,5	0,3	0,2

Comment: the choice of the flow resistivity of the porous medium influences sometimes considerably the acoustic performance of the silencer (at least: for some frequencies). In particular, the choice of a flow resistivity of the porous medium too big compared with the optimum required - as far as acoustics is concerned - can lead to a degradation of the performance for frequencies possibly within the range of interest.

For a given porous medium, an increase of the density involves - generally speaking - an increase of the flow resistivity (everything else supposed to be equal): for example, **attention has to be paid to the consequences of the use (in some locations…) of high**

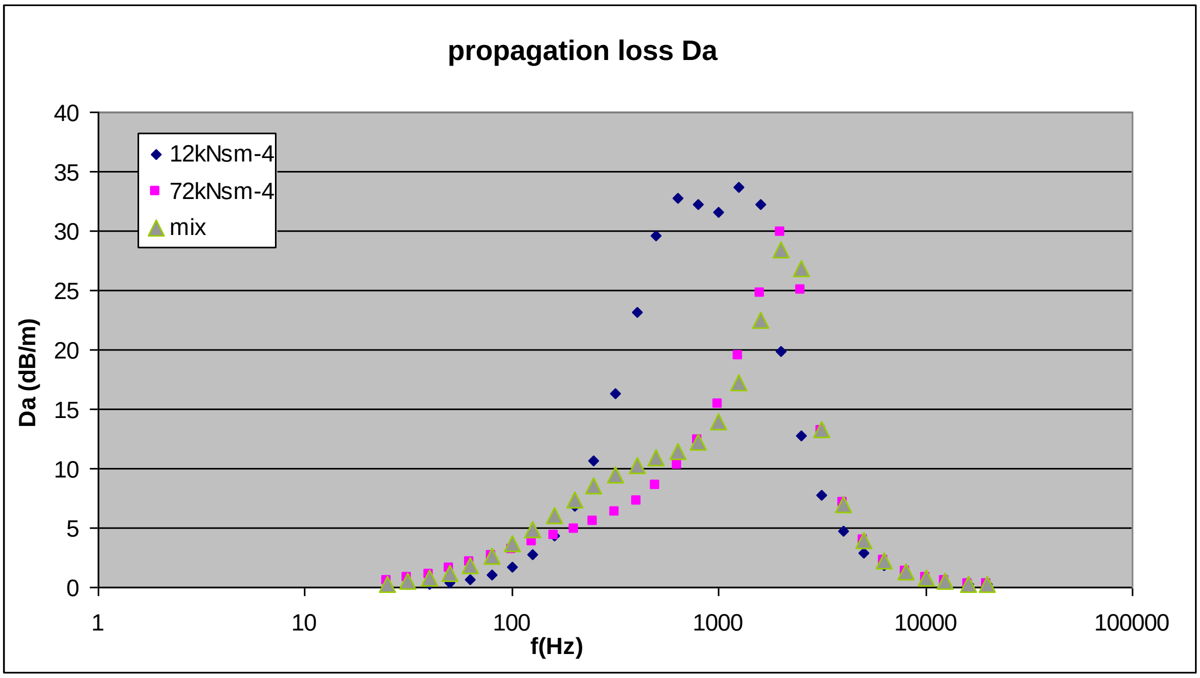
density rock wools using bonded short fibers producing possibly linings with a high flow resistance in some cases (especially when nothing is known regarding the properties of those materials in terms of flow resistivity, porosity…).

Effects of the properties of porous media in a laminated lining (illustration 1.5.2)

Imput data: a silencer is considered at (test) room pressure and temperature, with an open area ratio of 50%, the splitters having transverse solid partitions inhibiting the sound propagation along the duct axis inside the laminated lining consisting of:

- a surface layer being a porous medium having (at room temperature) a flow resistivity in the direction normal to the axis of the duct **σy1**=72 kNsm-4, a porosity **ø**=0.95 (model M76), with a thickness **ds**=0.02m. No series cloth is considered, no series perforated protection is considered.
- a core layer being a porous medium having (at room temperature) a flow resistivity in the direction normal to the axis of the duct **σy1=**12 kNsm-4, a porosity **ø**=0.95 (model M76), with a thickness **dc**=0.08m. No series cloth is considered, no series perforated protection is considered.

Illustration of one of the effects: see below the prediction of the propagation loss of the mix (laminated lining) and the comparison with a non-laminated lining made (with a thickness **d=ds+dc**=0.10m) either 100 % of the material of the surface layer or 100 % of the material of the core layer (see key in the graph)



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
12kNsm-4	0,1	0,2	0,3	0,4	0,7	1,1	1,7	2,7	4,3	6,8	10,7	16,3	23,2	29,6	32,7
72kNsm-4	0,5	0,8	1,1	1,6	2,1	2,6	3,2	3,8	4,3	4,9	5,5	6,3	7,3	8,6	10,2
mix	0,3	0,5	0,8	1,2	1,8	2,6	3,7	4,9	6,1	7,4	8,6	9,5	10,3	10,9	11,5

f1/3oct (Hz)	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
12kNsm-4	32,2	31,6	33,7	32,2	19,9	12,7	7,8	4,7	2,9	1,8	1,1	0,7	0,4	0,3	0,2
72kNsm-4	12,4	15,4	19,5	24,7	29,9	25,0	13,2	7,1	3,9	2,3	1,3	0,8	0,5	0,3	0,2
mix	12,3	13,9	17,2	22,5	28,4	26,8	13,3	7,0	3,9	2,3	1,3	0,8	0,5	0,3	0,2

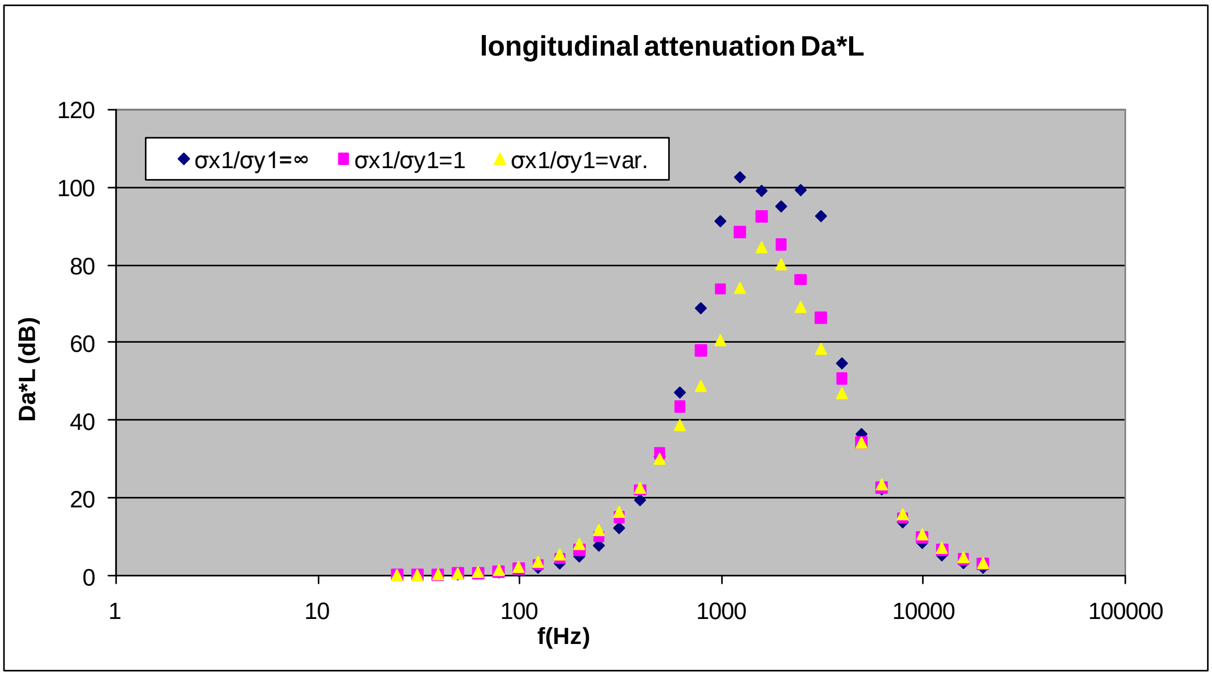
Comment: in case of a laminated lining, the choice of the flow resistivity of the porous media influences sometimes considerably the acoustic performance of the silencer (at least: for some frequencies). In particular, the choice of a flow resistivity of the porous medium for the surface layer too big compared with the optimum required - as far as acoustics is concerned - can (even with a thickness small compared to the total thickness of the lining) lead to a degradation of the performance for frequencies possibly within the range of interest.

See also the last paragraph of illustration 1.5.1

Effects of the conditions of propagation of sound inside the lining (illustration 1.5.3)

Imput data: a silencer is considered at (test) room pressure and temperature, with an open area ratio of 50%, the splitters being filled with a single porous medium having (at room temperature) a flow resistivity in the direction normal to the axis of the duct **σy1**=22332Nsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.05m. No series cloth is considered, no series perforated protection is considered. The longitudinal attenuation with a length **L**=1.5m is considered for the following cases, **σx1** being the flow resistivity of the porous medium in the direction parallel to the axis of the duct: **σx1/σy1**=∞ (absorber locally reacting), (*) **σx1/σy1**=1 (absorber bulk reacting), **σx1/σy1**=var. with var.=0.5

Illustration of one of the effects: see below the prediction of the propagation loss depending on the conditions of propagation of sound inside the porous medium (see key in the graph)(*)



f 1/3 oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
σx1/σy1=∞	0,1	0,1	0,2	0,3	0,5	0,8	1,2	2,0	3,1	4,9	7,7	12,2	19,4	30,6	47,1
σx1/σy1=1	0,1	0,2	0,3	0,5	0,7	1,1	1,8	2,8	4,4	6,7	10,1	15,0	22,1	31,6	43,6
σx1/σy1=var.	0,2	0,2	0,4	0,6	1,0	1,5	2,3	3,6	5,5	8,2	11,8	16,5	22,7	30,2	38,9

f 1/3 oct (Hz)	800	1000	1250	1600	2000	2500	3150	4000	5000	6300	8000	10000	12500	16000	20000
σx1/σy1=∞	68,8	91,2	102,5	99,0	95,0	99,2	92,5	54,6	36,4	22,2	13,7	8,4	5,2	3,2	2,0
σx1/σy1=1	58,0	74,0	88,6	92,8	85,4	76,5	66,5	50,8	34,3	22,6	14,9	9,9	6,5	4,3	2,9
σx1/σy1=var.	49,0	60,8	74,3	84,8	80,4	69,4	58,6	47,1	34,4	23,6	15,9	10,7	7,2	4,8	3,3

Comment: the conditions of propagation inside the porous medium of the lining (*) influences sometimes considerably the acoustic performance of the silencer (at least: for some frequencies). In particular, an overestimation of the (not always known) flow resistivity of the porous medium in the direction parallel to the axis of the duct can lead to a degradation of the performance for frequencies possibly within the range of interest.

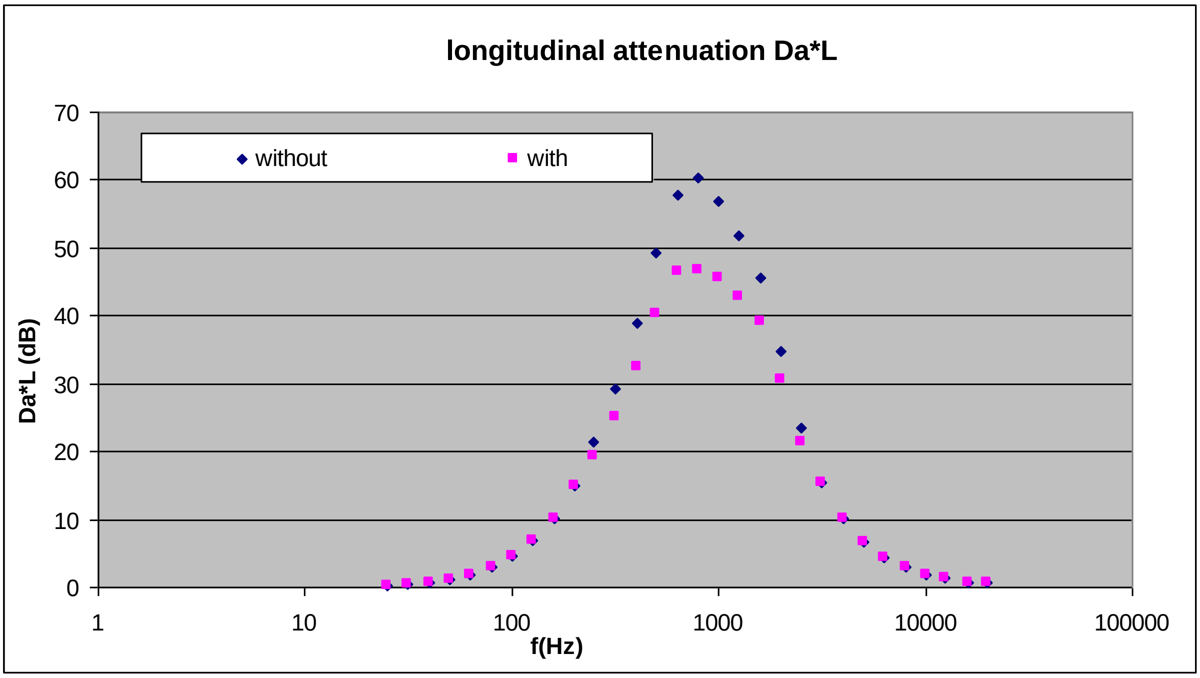
Attention has to be paid to the question of the possibility (or not, given the consequences in terms of construction modalities and corresponding costs) of an inhibition of the axial wave propagation inside the lining with transverse solid partitions.

* the case of an axial wave propagation inhibited by transverse very thick metal sheets (with a very short distance between them) acting as partitions is also referred to as **σx1/σy1**=∞ whatever the properties of the absorber are (else: no such partitions is considered)

Effects of the by-pass correction (illustration 1.5.4)

Imput data: a silencer is considered at (test) room pressure and temperature, with an open area ratio of 50%, the splitters having **no** transverse solid partitions being filled with a single porous medium homogeneous in directions parallel to and perpendicular to its surface, having (at room temperature) a flow resistivity in the direction normal to the axis of the duct **σy1**=12000Nsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.1m and a length **L**=2m. No series cloth is considered, no series perforated protection is considered. The longitudinal attenuation is considered with or without the by-pass correction.

Illustration of one of the effects: see below the prediction of the longitudinal attenuation depending on the existence or not of the limitation of the propagation loss (see key in the graph)



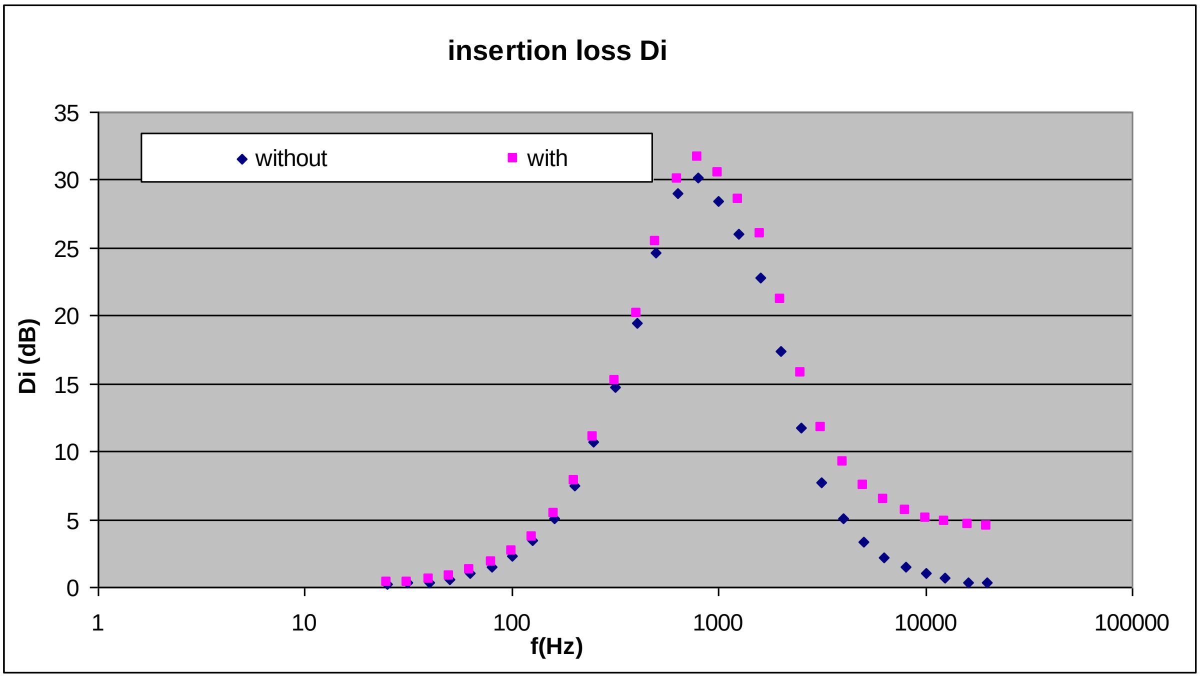
f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
without	0,3	0,5	0,8	1,2	1,9	3,0	4,5	6,8	10,2	14,9	21,3	29,3	38,9	49,2	57,9	60,4	56,8	51,9	45,6	34,8	23,5	15,4	10,1	6,6	4,3	2,9	1,9	1,3	0,8	0,6
with	0,3	0,5	0,8	1,2	1,9	3,0	4,5	6,8	10,2	14,9	19,3	25,0	32,4	40,4	46,5	46,7	45,5	42,9	39,1	30,6	21,4	15,4	10,1	6,6	4,3	2,9	1,9	1,3	0,8	0,6

Comment: the existence or not of a limitation of the propagation loss influences sometimes considerably the acoustic performance of the silencer (at least: for some frequencies). The influence of the conditions of propagation inside the lining has already been pointed out in a previous illustration: attention has also to be paid to the imperfection of the interface between the lining and the duct (leak occurring by-pass)

Effects of the reflection loss (illustration 1.5.5)

Imput data: a silencer is considered at (test) room pressure and temperature, with an open area ratio of 50%, the splitters having **no** transverse solid partitions being filled with a single porous medium homogeneous in directions parallel to and perpendicular to its surface, having (at room temperature) a flow resistivity in the direction normal to the axis of the duct **σy1=**12000Nsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.1m and a length **L**=1m. No series cloth is considered, no series perforated protection is considered. The insertion loss is considered with or without the reflection loss.

Illustration of one of the effects: see below the prediction of the insertion loss depending on the existence or not of the reflexion loss (see key in the graph)



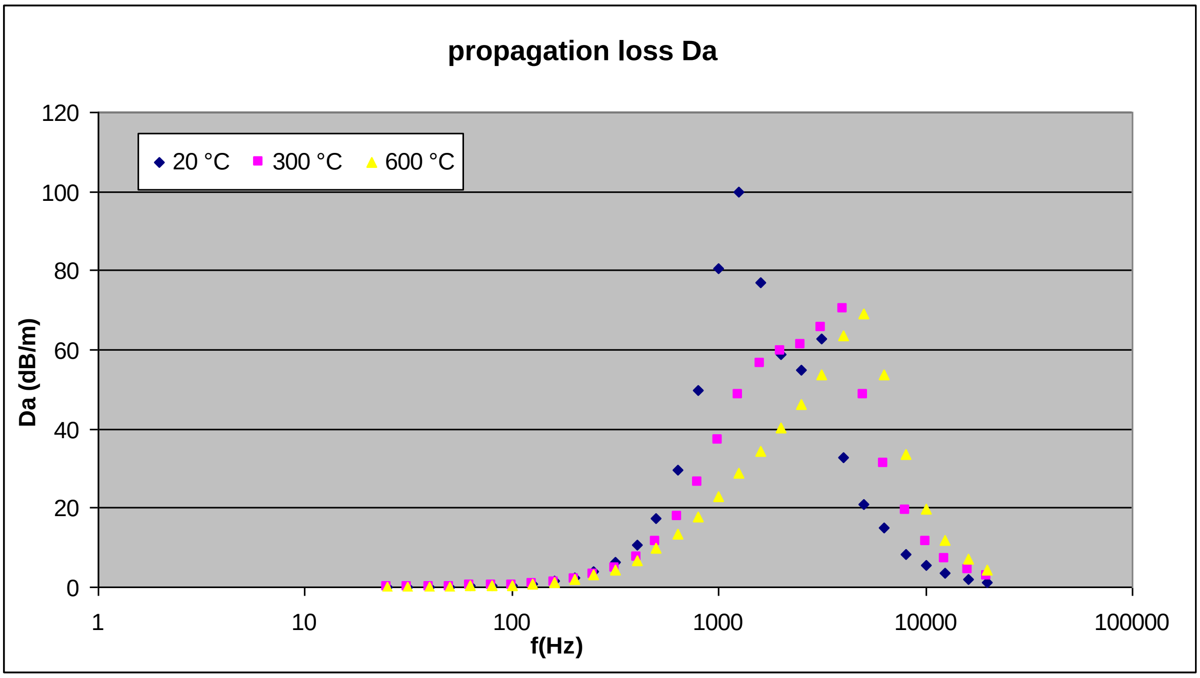
f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
without	0,2	0,3	0,4	0,6	1,0	1,5	2,3	3,4	5,1	7,5	10,7	14,7	19,5	24,6	29,0	30,2	28,4	26,0	22,8	17,4	11,8	7,7	5,1	3,3	2,2	1,5	1,0	0,7	0,4	0,3
with	0,4	0,4	0,6	0,8	1,3	1,8	2,6	3,7	5,4	7,8	11,1	15,2	20,2	25,5	30,0	31,7	30,5	28,6	26,0	21,2	15,8	11,8	9,2	7,5	6,4	5,6	5,1	4,8	4,6	4,5

Comment: the existence or not of the reflection loss influences the acoustic performance of the silencer (at least: for some frequencies). One should keep in mind that in the evaluation of the reflection loss includes the effect of higher modes with increased propagation loss in the air passage in the testing conditions used for the used data pool: different on site conditions may involve different reflection loss effects.

Effects of temperature (illustration 1.5.6)

Imput data: a silencer is considered (at (test) room pressure) on the one hand at (test) room temperature and on the other hand at high temperature with an open area ratio of 50%, the splitters having transverse solid partitions inhibiting the sound propagation along the duct axis inside the non-laminated lining consisting of a single porous medium having (at room temperature) a flow resistivity in the direction normal to the axis of the duct **σy1=12400** Nsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.05m. No series cloth is considered, no series perforated protection is considered.

Illustration of one of the effects: see below the prediction of the propagation loss depending on the temperature (see key in the graph)



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
20 °C	0,0	0,1	0,1	0,1	0,2	0,3	0,5	0,9	1,4	2,3	3,8	6,3	10,5	17,5	29,5
300 °C	0,0	0,1	0,1	0,1	0,2	0,3	0,5	0,8	1,3	2,0	3,1	4,9	7,6	11,6	17,9
600 °C	0,0	0,1	0,1	0,1	0,2	0,3	0,5	0,8	1,3	2,0	3,0	4,5	6,7	9,7	13,4

f1/3oct (Hz)	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
20 °C	49,9	80,5	99,9	77,0	59,0	55,0	62,9	32,7	20,8	15,0	8,4	5,5	3,4	2,1	1,3
300 °C	26,5	37,3	48,4	56,5	59,7	61,2	65,6	70,3	48,7	31,1	19,4	11,6	7,1	4,4	2,7
600 °C	17,8	22,7	28,7	34,4	40,1	46,1	53,8	63,6	69,0	53,5	33,4	19,7	11,8	7,0	4,3

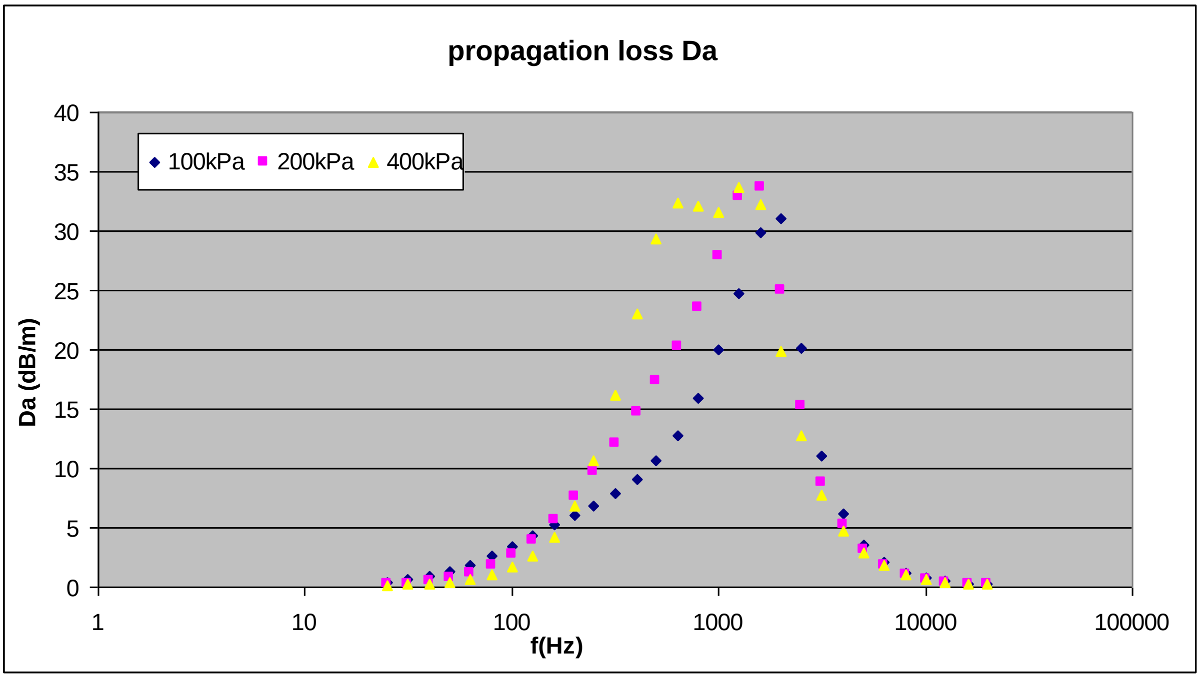
Comment: the temperature of the application influences sometimes considerably the acoustic performance of the silencer (at least: for some frequencies). For a given material, an increase of the temperature involves - generally speaking - an increase of the flow resistivity (everything else supposed to be equal).In particular, the choice of a flow resistivity of the porous medium (at room temperature) too big compared with the optimum required (at the temperature of the application) - as far as acoustics is concerned - can lead to a degradation of the performance for frequencies possibly within the range of interest.

See also the last paragraph of illustration 1.5.1

Effects of pressure (illustration 1.5.7)

Imput data: a silencer is considered at (test) room temperature and at a pressure from 100 to 400kPa with an open area ratio of 50%, the splitters having transverse solid partitions inhibiting the sound propagation along the duct axis inside the non-laminated lining consisting of a single porous medium having (at room temperature) a flow resistivity in the direction normal to the axis of the duct **σy1=48000** Nsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.1m. No series cloth is considered, no series perforated protection is considered.

Illustration of one of the effects: see below the prediction of the propagation loss depending on the pressure (see key in the graph)



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
100kPa	0,4	0,6	0,9	1,3	1,9	2,6	3,4	4,3	5,2	6,0	6,9	7,9	9,1	10,6	12,8
200kPa	0,2	0,3	0,5	0,8	1,2	1,8	2,8	4,0	5,6	7,6	9,7	12,1	14,7	17,4	20,3
400kPa	0,1	0,2	0,3	0,4	0,7	1,1	1,7	2,6	4,2	6,8	10,7	16,2	23,0	29,3	32,4

f1/3oct (Hz)	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
100kPa	15,9	20,0	24,8	29,9	31,1	20,1	11,0	6,2	3,5	2,1	1,2	0,8	0,5	0,3	0,2
200kPa	23,6	27,9	32,9	33,7	25,0	15,2	8,8	5,2	3,1	1,9	1,1	0,7	0,4	0,3	0,2
400kPa	32,1	31,6	33,7	32,2	19,9	12,8	7,8	4,7	2,9	1,8	1,1	0,7	0,4	0,3	0,2

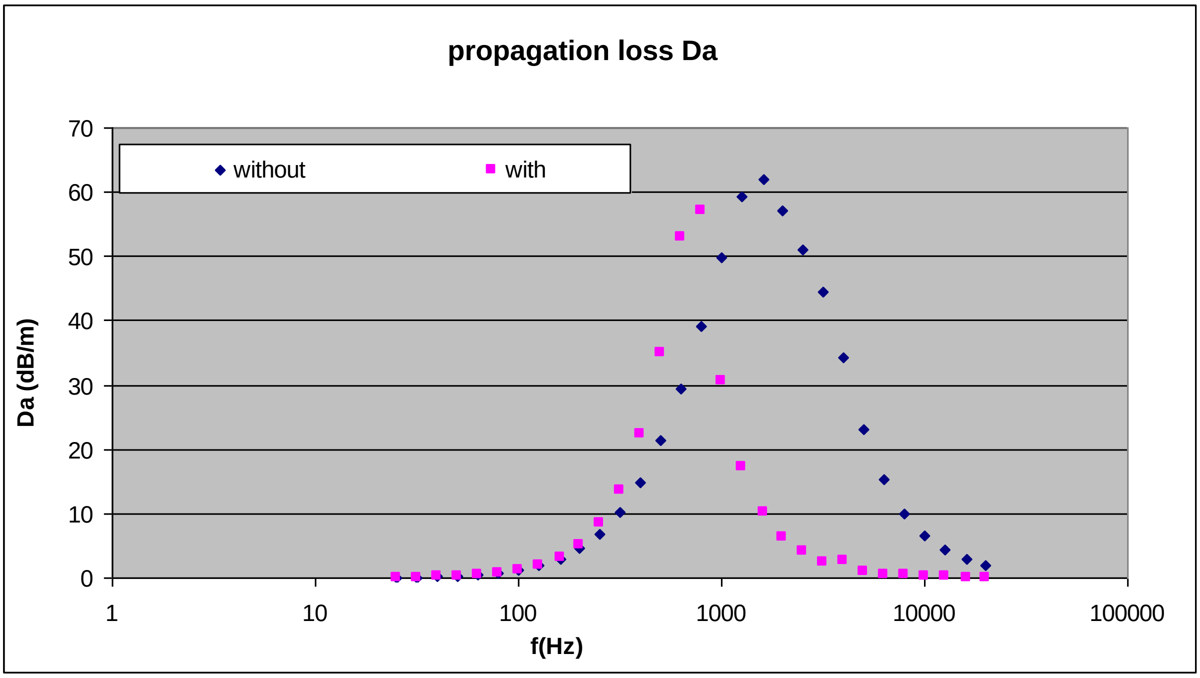
Comment: the pressure of the application influences sometimes considerably the acoustic performance of the silencer (at least: for some frequencies). Depending on the frequency range of interest, absorbers with a higher flow resistivity may be selected in case of pressure lines. But the choice of a flow resistivity of the porous medium too big compared with the optimum required (at the pressure of the application) - as far as acoustics is concerned - can lead to a degradation of the performance for frequencies possibly within the range of interest.

See also the last paragraph of illustration 1.5.1

Effects of a series cloth (illustration 1.5.8)

Imput data: a silencer is considered at (test) room pressure and temperature, with an open area ratio of 50%, the splitters having **no** transverse solid partitions inhibiting the sound propagation along the duct axis inside the non-laminated lining consisting of a single porous medium homogeneous in directions parallel to and perpendicular to its surface, having a flow resistivity **σy**=22332Nsm-4, a porosity **ø**=0.95 (model M76) with a thickness **d**=0.05m. The cloth consists of an impervious membrane (surface density 125 g/m2)

Illustration of the effect: see below the prediction of the propagation loss without and with the cloth



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
without	0,1	0,1	0,2	0,3	0,5	0,8	1,2	1,9	2,9	4,5	6,8	10,1	14,9	21,3	29,4
with	0,1	0,1	0,2	0,3	0,5	0,8	1,2	2,0	3,2	5,2	8,5	13,7	22,3	35,1	53,1

f1/3oct (Hz)	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
without	39,1	49,8	59,4	62,0	57,1	51,1	44,5	34,3	23,2	15,2	10,0	6,6	4,4	2,9	1,9
with	57,0	30,7	17,2	10,3	6,4	4,1	2,5	2,6	1,0	0,6	0,4	0,3	0,2	0,1	0,1

Comment: the choice of a series cloth influences sometimes considerably the acoustic performance of the silencer (at least: for some frequencies). In particular, the choice of a permeability of the cloth too small compared with the optimum required - as far as acoustics is concerned - can lead to a degradation of the performance for frequencies possibly within the range of interest (an increase of the performance being often obtained at low frequency due to the presence of a free vibrating foil).

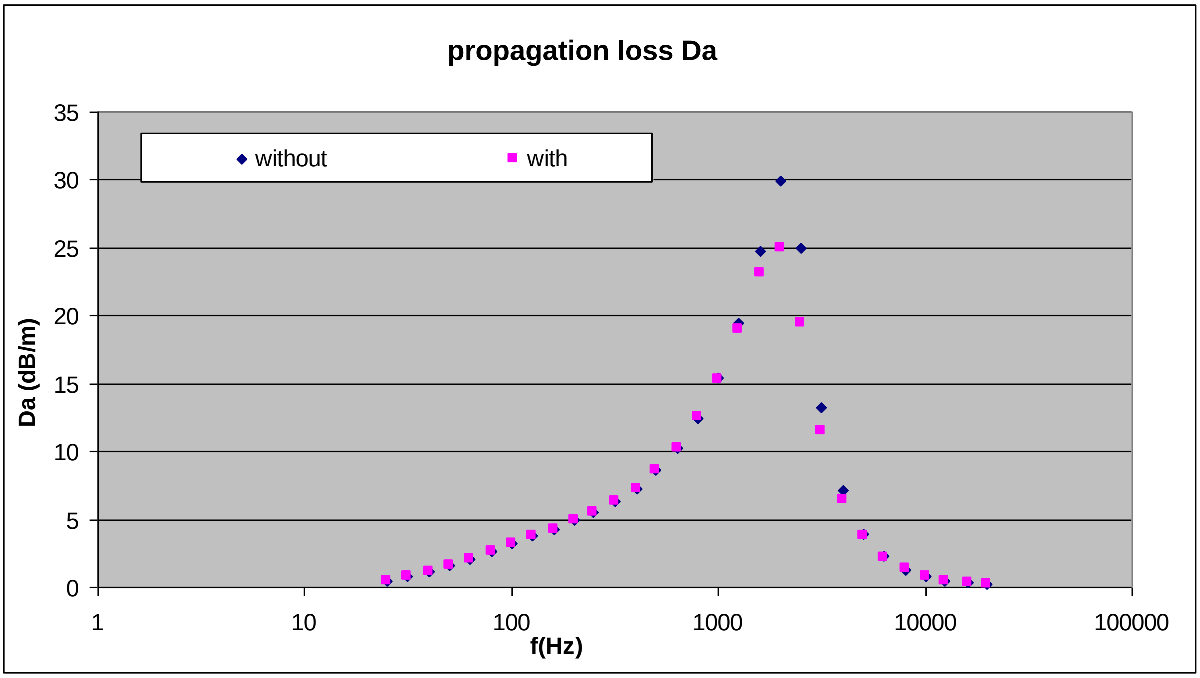
Attention has to be paid to the consequences of the use (in some locations…) of cloths producing possibly linings with a high flow resistance (especially when nothing is known regarding the properties of this materials in terms of flow resistivity, porosity…).

Attention has to be paid also to dust deposits in a position (in some cases) of involving effects comparable to the effect of a series cloth.

Effects of a series perforated protection (illustration 1.5.9)

Imput data: a silencer is considered at (test) room pressure and temperature, with an open area ratio of 50%, the splitters the splitters having transverse solid partitions inhibiting the sound propagation along the duct axis inside the non-laminated lining consisting of a single porous medium having a flow resistivity **σy**=72kNsm-4, a porosity **ø**=0.95 (model M76) with a thickness **d**=0.1m. The perforated protection consists of a sheet R3T5 (round holes with an hexagonal arrangement, diameter 3 mm, open area ratio ε=0.3265) of thickness 1 mm (general model MOI, model for the added impedances ROA)

Illustration of the effect: see below the prediction of the propagation loss without and with the perforated protection



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
without	0,5	0,8	1,1	1,6	2,1	2,6	3,2	3,8	4,3	4,9	5,5	6,3	7,3	8,6	10,2
with	0,5	0,8	1,2	1,6	2,1	2,7	3,2	3,8	4,3	4,9	5,5	6,3	7,3	8,6	10,3

f1/3oct (Hz)	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
without	12,4	15,4	19,5	24,7	29,9	25,0	13,2	7,1	3,9	2,3	1,3	0,8	0,5	0,3	0,2
with	12,5	15,3	19,0	23,1	25,0	19,4	11,5	6,5	3,8	2,2	1,4	0,8	0,5	0,3	0,2

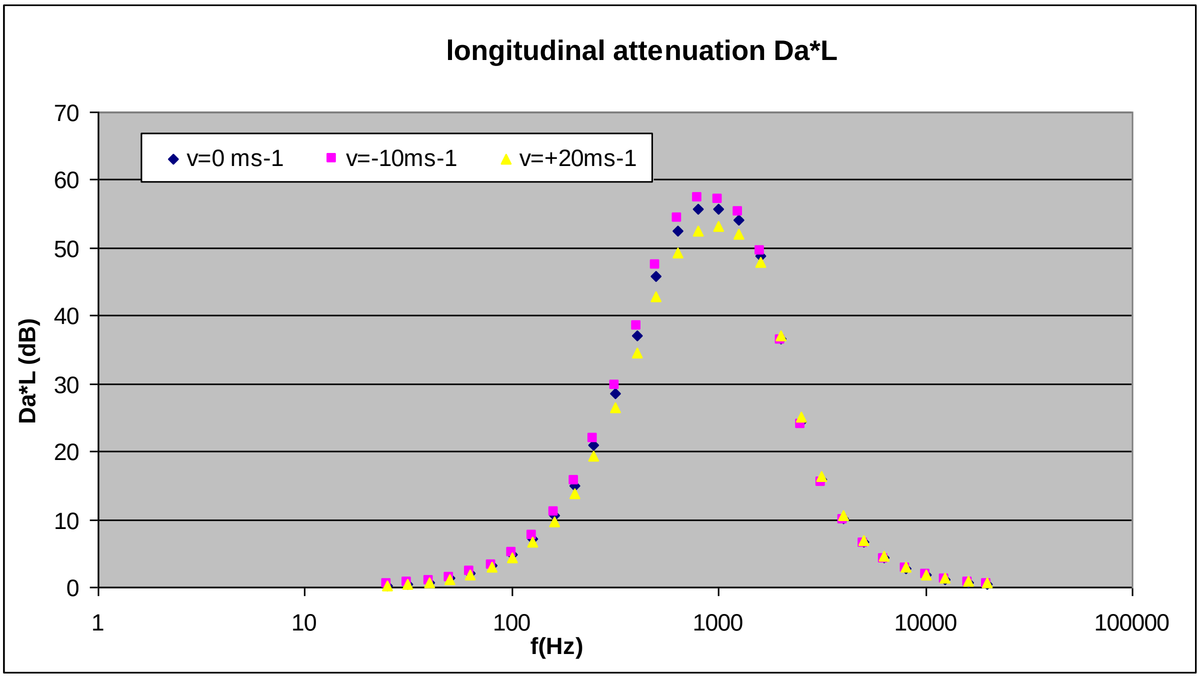
Comment: the choice of a perforated protection influences sometimes considerably the acoustic performance of the silencer (at least: for some frequencies). For a given geometry of holes and a given thickness, a decrease of the open area ratio involves - generally speaking - a decrease of the performance. In particular, the choice of a perforated protection with an open area ratio too small compared with the optimum required - as far as acoustics is concerned - can lead to a degradation of the performance for frequencies possibly within the range of interest (in the area of the maximum propagation loss, the performance is degraded in the example above despite a quite high open area ratio).

For a given perforated protection, the performance can decrease notably in case of a non-sufficiently pervious material at the rear: see also the last paragraph of illustration 1.5.1

Effects of the velocity of air flow (other than regenerated noise) (illustration 1.5.10)

Imput data: a silencer is considered at (test) room pressure and temperature, with an open area ratio of 50%, the splitters having **no** transverse solid partitions inhibiting the sound propagation along the duct axis inside the non-laminated lining consisting of a single porous medium homogeneous in directions parallel to and perpendicular to its surface, having (at room temperature) a flow resistivity in the direction normal to the axis of the duct **σy1**=15kNsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.1m and a length **L**=2m. No series cloth is considered, no series perforated protection is considered.

Illustration of one of the effects: see below the prediction of the longitudinal propagation depending on the mean flow velocity in the airways (see key in the graph)



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400
v=0 ms-1	0,3	0,5	0,8	1,3	2,1	3,2	4,8	7,2	10,5	15,0	21,0	28,5	37,1
v=-10ms-1	0,4	0,6	0,9	1,4	2,2	3,3	5,0	7,5	11,0	15,6	21,8	29,6	38,5
v=+20ms-1	0,3	0,5	0,8	1,2	1,9	2,9	4,4	6,6	9,7	13,8	19,4	26,5	34,6

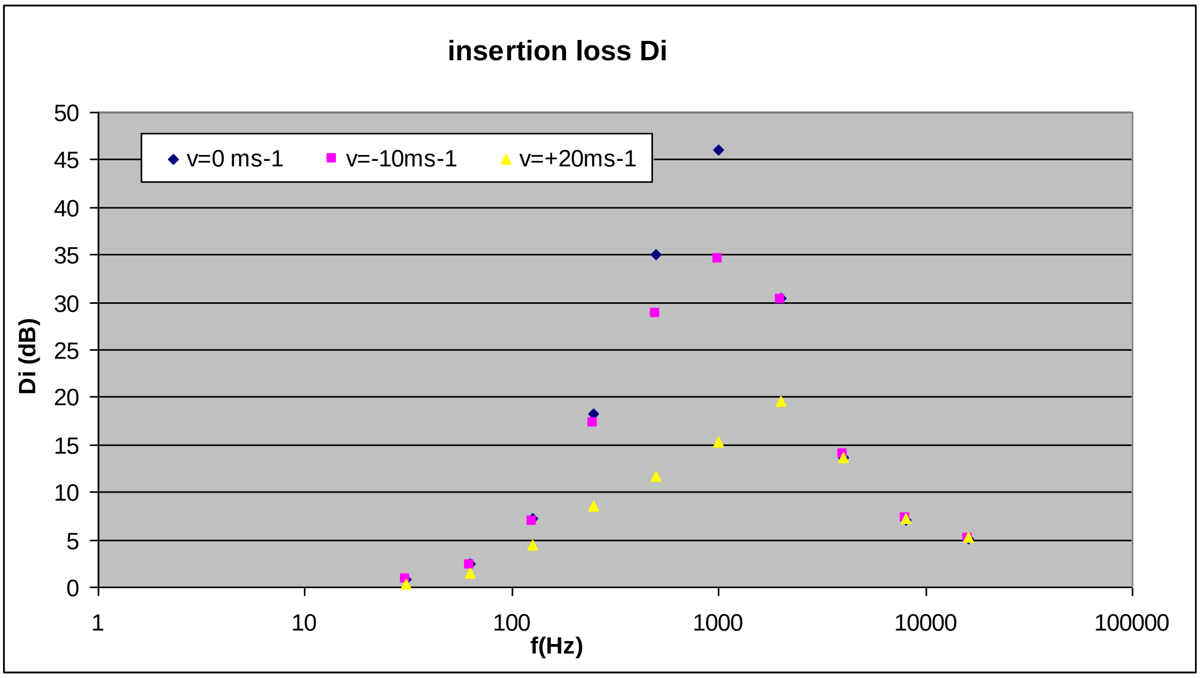
f1/3oct (Hz)	500	630	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k
v=0 ms-1	45,8	52,5	55,7	55,8	54,2	48,9	36,7	24,4	15,8	10,2	6,6	4,3	2,8	1,9	1,2	0,8
v=-10ms-1	47,4	54,3	57,3	57,2	55,3	49,4	36,4	24,0	15,5	10,0	6,5	4,2	2,7	1,8	1,2	0,8
v=+20ms-1	42,8	49,3	52,6	53,1	52,0	47,8	37,0	25,0	16,4	10,7	6,9	4,5	3,0	1,9	1,3	0,9

Comment: the flow velocity in the airways influences sometimes considerably the acoustic performance of the silencer (at least: for some frequencies), due to the change that can occur in the propagation loss affecting the longitudinal attenuation (relied to the conditions of propagation of sound in the lining and in the airways). Generally speaking, a negative airflow (direction of airflow and direction of propagation of sound opposite) involves an increase of the acoustic performance of the silencer when a positive airflow (same direction for airflow and propagation of sound) lead to a decrease of the acoustic performance of the silencer. In particular, the choice of a free area of the silencer (relied to the front section of the silencer and to the open area ratio) too small compared with the optimum required - as far as acoustics is concerned - can lead to a degradation of the performance for frequencies possibly within the range of interest.

Effects of the velocity of air flow (regenerated noise) (illustration 1.5.11)

Imput data: a silencer is considered at (test) room pressure and temperature, with an open area ratio of 50%, the splitters having **no** transverse solid partitions inhibiting the sound propagation along the duct axis inside the non-laminated lining consisting of a single porous medium homogeneous in directions parallel to and perpendicular to its surface, having (at room temperature) a flow resistivity in the direction normal to the axis of the duct **σy1**=15kNsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.1m and a length L=2m. No series cloth is considered, no series perforated protection is considered. A reflection loss and a limitation of the propagation loss are considered. The considered front section of the silencer is 2.5 m2. A noise source with an acoustic power of 80 dB/oct is considered.

Illustration of one of the effects: see below the prediction of the insertion loss depending on the mean flow velocity in the airways (see key in the graph)



f1/1oct (Hz)	31	63	125	250	500	1k	2k	4k	8k	16k
v=0 ms-1	0,8	2,4	7,2	18,3	35,1	46,1	30,4	13,6	7,1	5,1
v=-10ms-1	0,8	2,3	6,9	17,2	28,8	34,5	30,2	13,9	7,2	5,1
v=+20ms-1	0,4	1,4	4,4	8,5	11,6	15,3	19,6	13,7	7,2	5,2

Comment: the flow velocity in the airways influences sometimes considerably the acoustic performance of the silencer (at least: for some frequencies) due to the fact that the sound power level at the outlet of a silencer cannot be less than its self noise, leading to a reduction of the insertion loss in case of high sound power level due to the airflow. Attention has to be paid to limit the speed in the airways to acceptable values (taking into account the difference between unsilenced sound power level of the source and the insertion loss without taking into account the self noise) influenced - for a given flow rate - notably by the front area and the open area ratio of the silencer.

Effects of the unsilenced sound power spectrum (and of other uncertainties) (illustration 1.5.12)

Imput data: a silencer is considered at (test) room pressure and temperature, with an open area ratio of 50%, the splitters having transverse solid partitions inhibiting the sound propagation along the duct axis inside the non-laminated lining consisting of a single porous medium having (at room temperature) a flow resistivity in the direction normal to the axis of the duct **σy1**=12000kNsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.1m and a length **L**=1m.. No series cloth is considered, no series perforated protection is considered. The longitudinal attenuation for the 1/1 octave band of central frequency 250 Hz is considered for various sound power spectra of the unsilenced source Lw0, taking into account the propagation loss Da computed (on the occasion of the first illustration of this §) for the corresponding 1/3 octave bands: 6.8 dB/m at 200 Hz,10.7 dB/m at 250 Hz, 16.3 dB/m at 315 Hz.

Illustration of one of the effects: see below the calculation of the longitudinal attenuation for the 1/1 octave band depending on the sound power spectrum of the unsilenced source (see key in the table)

		1/3 octave frequency band central frequency (Hz)			1/1 octave band central frequency (Hz)
		200	250	315	250
Case 1	Lw0 (dB ref1E-12W)	75.2	75.2	75.2	80
	Da*L (dB)	6.8	10.7	16.3	
	Lw0 - Da*L (dB ref1E-12W)	68.4	64.5	58.9	70.2
	longitudinal attenuation for the 1/1 octave band				**9.8**
Case 2	Lw0 (dB ref1E-12W)	68.0	75.0	78.0	80
	Da*L (dB)	6.8	10.7	16.3	
	Lw0 - Da*L (dB ref1E-12W)	61.2	64.3	61.7	67.4
	longitudinal attenuation for the 1/1 octave band				**12.6**
Case 3	Lw0 (dB ref1E-12W)	78.0	75.0	68.0	80
	Da*L (dB)	6.8	10.7	16.3	
	Lw0 - Da*L (dB ref1E-12W)	71.2	64.3	51.7	72.0
	longitudinal attenuation for the 1/1 octave band				**8.0**

Comment: the sound power spectrum of the unsilenced source influences sometimes considerably the acoustic performance of the silencer (at least: for some frequencies) in terms of longitudinal attenuation per 1/1 octave band (and so in terms of insertion loss) due to the combination of possibly high frequential variation on the one hand: of the performance of the silencer and on the other hand: of the spectrum of the source (especially in case of pure tones such as produced by rotating machines). Only in the case of a pink spectrum for the unsilenced noise source is the averaging of 1/3 octave band performance leading to a correct result for the 1/1 octave band longitudinal attenuation.
Attention has to be paid by the user of the software to use an 1/3 octave band spectrum for accurate sizing of dissipative silencers (and to take a safety margin for the uncertainty of the available input data and of the conditions of on-site installation of the silencer).

Appendix to Section 1: list of symbols

General

f: frequency (Hz)
Lw0: sound power level without soundproofing equipment (dB ref. 1pW)
Lw1: sound power level with soundproofing equipment (dB ref. 1pW)
t: time (s)

Set of materials

ilim: limit set index
imax: maximum set index
ξ **:** total number of cloths and perforated protections accounted as porous media i.e. not accounted as series cloth (resp. series perforated protections) using electro acoustic analogie

Dry air

a: diffusivity (m^2/s)
c: (adiabatic) velocity of sound (ms^{-1})
c_p : specific heat (capacity) (at constant pressure) (J/kg/K)
C_s: adiabatic compressibility (Pa^{-1})
C_T: isothermal compressibility (Pa^{-1})
k: wave number (rad/m)
K_s: adiabatic bulk modulus (Pa)
K_T: isothermal bulk modulus (Pa)
t: temperature (°C)
P: static/atmospheric pressure (Pa)
Pr: Prandtl number
R**:** gas constant (J/kg/K)
V: volume (m^3)
Z: characteristic impedance (Nsm^{-3})

β: coefficient of thermal expansion
Γ: propagation constant (rad. m^{-1})
η : dynamical viscosity (Nsm^{-2})
λ: thermal conductivity (W/m/K)
λ: wavelength (m)
ν : kinematic viscosity **(**m^2/s)
ρ: density (kg/m3)

subscript / superscript		subscript	superscript
for normal conditions		0	N
for test (room) conditions		0	*
for service conditions	front atmosphere	0	
	rear atmosphere	0	**

Porous media

a', a'': coefficients for the expression of Γ_{an}
b', b'': coefficients for the expression of Z_{an}
c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8 : coefficients for the expression of Γ_{an} and Z_{an}
C_{seff}: adiabatic compressibility (Pa^{-1})
E: non-dimensional parameter related to frequency, flow resistivity and density of dry air
K_{seff}: adiabatic bulk modulus (Pa)
RG: (bulk) density (kg/m^3)
Z_a: characteristic impedance (Nsm^{-3})
Z_{an}: normalized characteristic impedance

α', α'': exponents for the expression of Γ_{an}
β', β'': exponents for the expression of Z_{an}
α_∞: (high frequency limit of the) tortuosity
Γ_a: propagation constant (rad.m^{-1})
Γ_{an}: normalized propagation constant
Γ_{ax}: propagation constant in the x-direction (rad.m^{-1})
Γ_{ay}: propagation constant in the y-direction (rad.m^{-1})
Λ': thermal characteristic length (m)
Λ : viscous characteristic length (m)
ρ_{eff}: effective density (kg/m^3)

ø : (open) porosity
σ: (static) air flow resistivity (=specific flow resistance) (Nsm^{-4})
σ1x: (static) air flow resistivity in the x-direction for porous medium of set 1(Nsm^{-4})
σ1y: (static) air flow resistivity in the y-direction for porous medium of set 1(Nsm^{-4})

Note: subscript i for set i except for σ1x and σ1y

Cloths

d’: thickness (m)
M’: surface density (kg/m^2)
R’: superficial flow resistance (Nsm^{-3})
Rp’: parallel resistance (losses due to mounting) (Nsm^{-3})

Note: subscript i for set i

Perforated protections

a: diameter of holes / width of slit (m)
d’’: thickness (m)
M’’: surface density (kg/m^2)
R’’: series flow resistance (Nsm^{-3})
Rp’’: parallel resistance (losses due to mounting) (Nsm^{-3})
ε: open area ratio

Note: subscript i for set i

Silencer

a: $a=h*2*\pi^{-0.5}$ (m)
2a: width of airway (m)(for mounting C0 only)
abulk: cf. step [F] (m)
alocal: cf. step [F] (m)
A : area of the duct above and below the silencer (m^2)
Af: area of the overall section of the silencer (m^2)
Af*: area of the duct above and below the silencer when the area of the duct is not equal to the area of the overall section of the silencer (m^2)
Ap : free area of the silencer (passage area of the airways) (m^2)
B: width for mounting R, R’’, RPTR, RPTR’’, RPTL, RPTL’’(m)
d: overall thickness of the acoustic structure (m)
d=2d/2: for dissipative silencers, thickness of extreme inner lagging (for mountings R, C1, C2 only) = thickness of lining (for mountings Q, C0 only) (m)
2d: for dissipative silencers, thickness of central splitters (for mountings R, R’’) = diameter of central pod (for mountings C1, C2 only) = thickness of intermediate splitter (for mounting C2 only) (m)
dbulk: cf. step [F] (m)
dlocal: cf. step [F] (m)
d*=2d*/2: for resonant silencers, thickness of extreme inner lagging (for mountings RPTR, RPTL only)
2d*: for resonant silencers, thickness of central splitters (m)
Da: propagation loss (dB/m)
Da.L:longitudinal attenuation (dB)
Di: insertion loss with flow and self noise (dB)
Di’: insertion loss with flow without self noise (dB) (Di’=Da*L+Dk+Dr)
Dk: limitation of the propagation loss (dB/m)
Dr: reflection loss (dB)
D0: overall diameter for mounting C0 (m)
D1: overall diameter for mounting C1 (m)
D2: overall diameter for mounting C2 (m)
fco: cut-off frequency of the duct (Hz)
h=2h/2: for dissipative silencers, width of extreme air way (for mounting R’’ only) (m)
2h: for dissipative silencers, width of central airways (for mounting R” only) = width of the airways (for mountings R, C1, C2, Q) (m)
hbulkl: cf. step [F] (m)
hlocal: cf. step [F] (m)
H: height for mounting R, R’’(m)
Hs: for a resonant silencer only (half) airway in the chamber (m)
Hsbulkl: for a resonant silencer only cf. step [F] (m)
Hslocal: for a resonant silencer only cf. step [F] (m)
L: length without aerodynamic extremities (m)
Ls: for a resonant silencer only length of the chamber (m)
M: Mach number
N: for a dissipative silencer only number of central splitters (for mounting R only)

N'': for a dissipative silencer only number of central splitters (for mounting R''only)
N*: for a resonant silencer only number of central splitters (for mounting RPTR, RPTL only)
N''*: for a resonant silencer only number of central splitters (for mounting RPTR'', RPTL''only)
Q: overall width=overall height for mounting Q (m)
Qm: mass flow rate (kg/s)
Qv: volume flow rate (m3/s or m3/h or Nm3/h)
Sa: for a resonant silencer only width between necks of chambers (m)
Ss: for a resonant silencer only width of necks of chambers (m)
T: for resonant silencers only period width such as T=Ss+Sa (m)
Vf: speed of airflow in the area Af (m/s)
Vf*: speed of airflow in the area Af* (m/s)
Vp: speed of airflow in the area Ap (m/s)

Δd: for resonant silencers with a rear lining only thickness such as Δd=d*-d (m)
Λ=d/h
ζf: total pressure loss coefficient in relation with airflow speed Vf
ζf*: total pressure loss coefficient in relation with airflow speed Vf*
ζp: total pressure loss coefficient in relation with airflow speed Vp
θ : angle of the branches of the Pine Tree spiltters

Miscellaneous

See also corresponding § in General considerations and in Section 2

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Section 1A: computation of silencers with discontinued splitters (MODULE 1A of the software)

1A.1: Introduction

Terms and definitions

For the needs of the present user's manual, the following terms and definition apply (see NF EN ISO 14163 Acoustics - Guidelines for noise control by silencers, 1999):

Silencer: device reducing the acoustic transmission in a duct, a pipe or an aperture, without preventing the carriage of the fluid

Dissipative silencer: silencer attenuating the wideband sounds with a relatively low pressure loss and converting partially the acoustic energy into heat by friction on tubes having a porous or fibrous structure

Mountings and geometry

Silencers having rectangular cross sections are frequently used for industrial applications.

For dissipative silencers with discontinued splitters, mountings for which predictions can be done with the software SILDIS are shown in fig.1A1

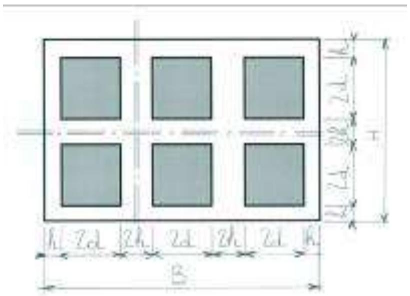


fig.1A.1 cf. worksheet CODIS-1A

mounting RD

Key of the previous figures

2d: thickness of central splitters (for mountings RD
h=2h/2: width of extreme air way (for mounting RD)
2h: width of central airways (for mounting RD)
L: length of the silencer without aerodynamic extremities
Nd: number of central splitters (for mounting RD);

Concerning the area of the duct upstream and downstream (above and below the silencer) A compared to the area of the overall section of the silencer Af, predictions with the software SILDIS can be done:

- for mountings RD with A = Af

Section of the duct above and below the silencer A depending on mounting	R, R''
A=Af	B*H

The direction parallel to the axis of the duct is referred to as **x**, the direction normal to the axis of the duct along the width B is referred to as **y,** the direction normal to the axis of the duct along the height H is referred to as z according to the fig. 1A.2 below

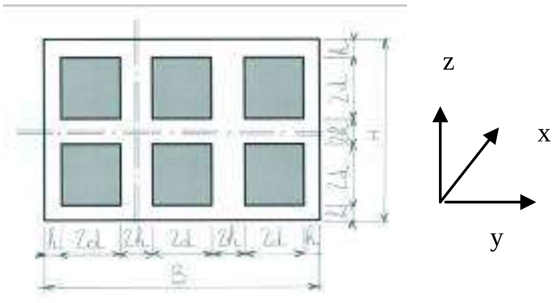


fig.1A.2

1A.2: Scientific and technical background

The prediction of acoustic and aerodynamic performances of dissipative silencers with SILDIS is founded on a scientific and technical background in relation with:

- analytical models for taking into account the properties of materials and various physical phenomena useful on the occasion of the computation
- measurement results for feeding some of those models and for allowing the necessary improvement (through correction factors) of the correlation between some calculations and on site observations

For a rectangular silencer, the obtained results are comparable with the standardized measurement with the plane wave excited alone as much as possible: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units - Insertion loss, flow noise and total pressure loss (2004).

1A.2.1 Thermodynamics and fluid dynamics:

- **Steps of the computation**

Step [a-1A]

All computations have been gathered in this single step for the sake of simplicity.

- ***Bibliography (references) :***

[a1-1A]	
[a2-1A]	
[a3-1A]	
[a4-1A] -	
[a5-1A]	

- ***Comments in relation with partial derivatives:***

Partial derivatives (and related quantities), which are usually employed to measure the equation of state of the fluid near the equilibrium state (with various notations according bibliographic sources) are written for the purpose of the present user's manual with the following notations:

- the **isothermal compressibility** of dry air is referred to as C_T

$$C_T = -\frac{1}{V}\left[\frac{\partial V}{\partial P}\right]_T = \frac{1}{\rho}\left[\frac{\partial \rho}{\partial P}\right]_T$$

- the **isothermal bulk modulus** of dry air is referred to as K_T with $K_T=1/C_T$

- the **adiabatic compressibility** of dry air is referred to as C_s

$$C_s = -\frac{1}{\kappa V}\left[\frac{\partial V}{\partial P}\right]_T = \frac{1}{\kappa\rho}\left[\frac{\partial \rho}{\partial P}\right]_T \quad \text{because } C_s = C_T/\kappa$$

- the **adiabatic bulk modulus** of dry air is referred to as K_s with $K_s=1/C_s$

- the **coefficient of thermal expansion** of dry air is referred to as β

$$\beta = \frac{1}{V}\left[\frac{\partial V}{\partial T}\right]_P = -\frac{1}{\rho}\left[\frac{\partial \rho}{\partial T}\right]_P$$

- ***Other comments:***

- when used the **density** of dry air ρ is computed according various models as shown in the table below:

model	MAR	**MEC**
source	[a1-1A] using ideal gas law (derived from MARiottes's law) (*)	[a1-1A] using a regression

* the **gas constant of dry air** R (J/kg/K) is set to 287 or **287.053** or 287.10 depending on the eponym selected model

- when used the **dynamical viscosity** of dry air η is computed according various models as shown in the table below:

model	SUT	VER	**MEC**	IDE
source	[a2-1A] using SUTherland 's law)	[a4-1A]	[a1-1A] using a regression	[a2-1A] using a regression
limiting temperature	-20 to 800 °C	?	-173.15 to 926.85 °C	-20 to 800 °C

Conversion factors	micropoise	centipoise	poise = g/cm/s	kg/m/s = Nsm-2
micropoise	1	10^{-4}	10^{-6}	10^{-7}
centipoise	10^{4}	1	10^{-2}	10^{-3}
poise = g/cm/s	10^{6}	10^{2}	1	10^{-1}
kg/m/s = Nsm-2	10^{7}	10^{3}	10	1

- when used the **kinematic viscosity** of dry air ν is computed from [a1-1A]

Note : ν = η/ρ

Conversion factors	centistokes = mm2/s	stokes = cm2/s	m2/s
centistokes = mm2/s	1	10^{-2}	10^{-6}
stokes = cm2/s	10^{2}	1	10^{-4}
m2/s	10^{6}	10^{4}	1

- when used the **adiabatic exponent** of dry air κ is computed according various models as shown in the table below:

model	INV	**MEC**
source	(*)	[a1-1A] using a regression
limiting temperature	-	-73.15 to 926.85 °C

*κ is set to 1.399 or 1.400 or 1.401 or **1.402** depending on the eponym selected model

- when used the **specific heat (capacity) (at constant pressure)** of dry air c_p is computed according various models as shown in the table below:

model	MEC	**MEC2**	KRA
source	[a1-1A] using a regression for a (the regression for c_p being in error)	[a1-1A] using a regression for Pr (the regression for c_p being in error)	[a3-1A] using a regression
limiting temperature	-73.15 to 926.85 °C	-173.15 to 926.85 °C	-20 to 800 °C

Conversion factors	J	cal
J	1	0.2388
cal	4.1868	1

- the following relation apply: $\kappa - 1 = \dfrac{\beta^2.T}{C_S.c_p.\rho}$
- when used the **thermal conductivity** of dry air λ is computed according various models as shown in the table below:

model	**MEC**	KRA
source	[a1-1A] using a regression	[a3-1A] using a regression
limiting temperature	-173.15 to 926.85 °C	-20 to 800 °C

Conversion factors	J	cal
J	1	0.2388
cal	4.1868	1

- when used the **diffusivity** of dry air a is computed from [a1]

  Note : $a = \lambda/\rho/c_p$

- when used the **Prandtl number** of dry air Pr is computed according various models as shown in the table below:

in case of model for c_p	**MEC**	MEC2	KRA
source	[a1-1A] from η, c_p and λ	[a1-1A] using a regression	[a3-1A] from η, c_p and λ
limiting temperature	-73.15 to 926.85 °C	-173.15 to 926.85 °C	-20 to 800 °C

  Note : $Pr = \nu/a = \eta/\rho/a = \eta.c_p/\lambda$

- when used the **(adiabatic) sound velocity** in dry air c is computed from [a5-1A]

  Note : $c = (K_s/\rho)^{0.5}$

- when used the **characteristic impedance** of dry air Z is computed from [a1-1A]

  Note : $Z = \rho c$

1A.2.2 Acoustics:

- **Bloc diagram for rectangular dissipative silencers:** the computation scheme for rectangular dissipative silencers is as shown on fig 1A.3 below

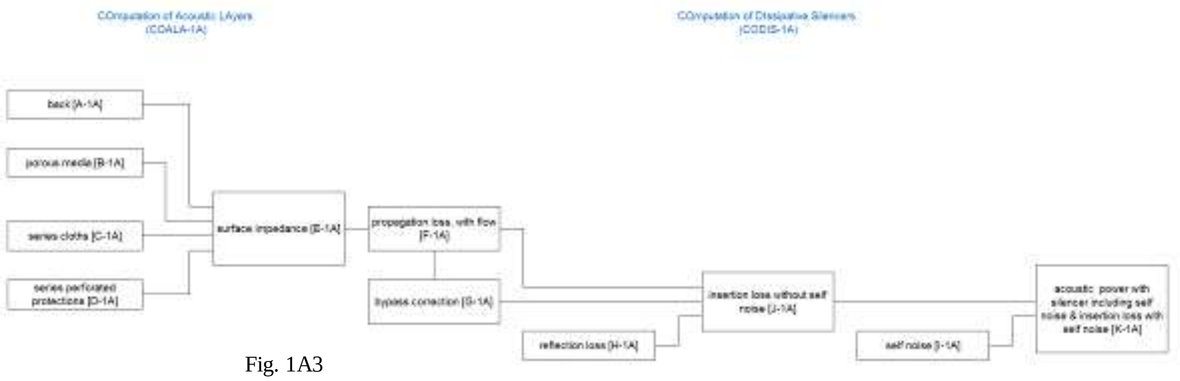


Fig. 1A3

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRxx-002x] pages 6 to 7, report [PhRxx-006x] pages 2 to 3, report [PhRxx-015x]

Note 2: the main steps (the steps involving a physical modeling) being referred to as [A-1A] to [K-1A] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity; the calculation is carried out with the hypothesis of plane waves, typically regarded as the least attenuated mode (only for step [H-1A] are other modal contributions taken into account)

Note 3: analytical calculations are involved in steps [A-1A] and [J-1A] to [K-1A]; empirical methods are involved in steps [G-1A] to [I-1A]

Note 4: step [F-1A] is depending on the conditions of axial sound propagation inside the lining

Note 5: the bloc diagram above is suitable for rectangular dissipative silencers, for the mounting SD .

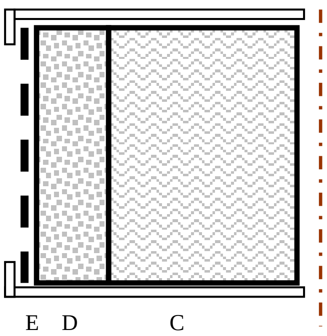
- **Steps of the computation**

Steps [A-1A] to [F-1A]

Those steps aim at taking into account the properties of the filling of splitters (cf. fig 1A.4)and at calculating the **propagation loss with flow of the silencer.**

Sketch **Nomenclature**

Airway



land mark	element
E	series perforated protection
D	series cloth
C	porous medium

Fig. 1A4

- ***Bibliography (references) :***

[A1-1A] - -	

- ***Comments :***

No comment

Step [G-1A]

This step aims at taking into account a **bypass correction** (i.e. a limitation of the propagation loss in case of a length of the silencer over 1m: indeed, compared with the estimation obtained with an hypothesis of proportionality of the performance to the length of the silencer, in order to predict an insertion loss).

- ***Bibliography (references) :***

[G1-1A] -	
[G2-1A] -	
[G3-1A]	

- ***Comments :***

The bypass correction (**Dk** in dB) is basically computed at frequency steps of 1/3 octave:

for L≤1m: Dk = 0 and **for L>1m: Dk = ΔD * (1 – L)** with **ΔD** in dB/m

- **general case**

An extrapolation of the original value of **ΔD** mentioned in [G1-1A] is used for SILDIS, allowing calculations in an extended range of values of **σy1** for values of Λ=d/h to be précised on the occasion of a future revision of this user's manual

Note 1: the data pool used for the determination of the original value of **ΔD** mentioned in [G1-1A] is related to splitters filled with 1 porous medium with a flow resistivity **σx1 =? σy1** from 9 to 15 kNsm^{-4}: no influence of the speed of the airflow seems to be taken into account for the computation, no influence of a series cloth seems to be taken into account for the computation, no influence of a series perforated protection seems to be taken into account for the computation

Note 2: in [G3-1A] is mentioned for [G2-1A] basing [G1-1A] complementary information. The data pool used for **ΔD** is related to splitters "in 1 piece" with a thickness 2d=0.1 or 2d=0.2 m with Λ=d/h=0.5 to 4

Model	**FRO**	ZER
Bypass correction	as above	no limitation

*although at the time of the present user's manual the conditions of the measurement of the data pool ([G1-1A],[G2-1A]) are not known with accuracy, one can consider that: **Dk = Dk1 + Dk2** (the 2 terms being presently not known separately) with:

✓ **Dk1** to be accounted for the vibration transmission along the duct wall, for the sound transmission over the duct wall, for the vibration transmission along the splitter frame (as described in [G1-1A] and for the imperfection of the interface between the lining and the duct

✓ **Dk2** to be accounted for the inhomogeneity of the used absorber in directions parallel to and perpendicular to its surface: a unique model is used for taking into account the limitation of propagation whatever **σx1/σy1** is (may be that this correction should be used only in the case of an inhomogeneous absorber in directions parallel to and perpendicular to its surface when the hypothesis **σx1/σy1**=1 is used for the computation).

For those reasons, the value obtained by the means of the unique model FRO has to be considered as a typical general estimation of the limitation of the propagation loss useful when no accurate regression is available for a silencer with a particular filling and particular modalities of construction (this is often the case)

Step [H-1A]

This step aims at taking into account the **reflection loss in the silencer**, in order to predict an insertion loss.

- ***Bibliography (references) :***

[H1-1A] -	
[H2-1A] -	
[H3-1A]	

- ***Comments :***

The reflection loss (**Dr** in dB) is basically computed at frequency steps of 1/21 octave (then averaged per 1/3 octave frequency band).

- **general case:** no influence of the speed of the airflow is taken into account for the computation

Model	**MUL** (*)	ZER
Reflection loss	as above (higher modes integrated)	no reflection

* No influence of a series cloth is taken into account for the computation, no influence of a series perforated protection is taken into account for the computation. The data pool used for **Dr** is related to splitters with a thickness 2d=0.1 or 0.2 or 0.3 m, filled with 1 porous medium with a flow resistivity **σx1** = **σy1** from 9 to 15 kNsm-4 (an extrapolation of **Dr** with a different thickness has been used). At the time of the present user's manual the conditions of the measurement of the data pool ([H2-1A],[H3-1A]) are not known with accuracy, especially the higher modes propagating in the duct in relation with the characteristics of the testing facility mentioned in [H2-1A] (with a front section from 0.5m*0.5m to 1.3m*0.5m). For those reasons, the value obtained by the means of the unique model MUL has to be considered as a typical estimation of the reflection loss for a duct of dimensions comparable to testing facility mentioned in [H2-1A] when no accurate information is available regarding the higher order modes (this is often the case).

Step [I-1A]

This step aims at taking into account the **self noise of the silencer (noise produced by the airflow).**

For dissipative silencers

- ***Bibliography (references) :***

[I1-1A]	
[I2-1A]	
[I3-1A]	
[I4-1A]	
[I5-1A]	
[I6-1A]	
[I7-1A]	
[I8-1A]	
[I9-1A] -	
[I10-1A]	
[I11-1A] -	

- ***Comments:*** the self noise (acoustic power of flow noise **Lw** in dB ref 1E-12W) is basically computed at frequency steps of 1/1 octave.

  - ***for the mounting of the worksheet CODIS-1A*** *(RD)*, the determination of the self noise is done according various models as shown in the tables below:

model	DN1	DN2	NF1	NF2	2081A
source	[I1-1A]	[I1-1A]	[I2-1A]	[I2-1A] (*)	[I3-1A] (**) (***)

model	**2081B**	2081R	2081C1	MUN	VER
source	[I4-1A] (**)(***)	[I5-1A] (**)(***)	[I5-1A] (**)(***)	[I8-1A] (***)	[I9-1A] (***)

(*) B (dB) and δ (m) are input data (**) with an additional correction for temperature
(***) with an additional correction for pressure

- for the models 2081 and 3733, a spectral correction is used according various models as shown in the tables below:

model	2081	**FRO**	3733
source	[I5-1A]	[I11-1A]	[I7-1A]

Warning: at the time of the writing of this manual, all the consequences of the choice of one or the other model are not known with accuracy. The choice of the model can be done by the user allowing tests and feed-back.

Step [J-1A]

This step aims at calculating the **insertion loss without taking into account the self noise.**

- ***Bibliography (references) :***

[J1-1A] -	

- ***Comments :***

The insertion loss without taking into account the self noise (**Di’** in dB) is computed at frequency steps of 1/3 octave (then calculated per 1/1 octave frequency band for a reference acoustic power spectrum **Lw0** in dB ref 1E-12W).

Di’ = Da * L + Dk + Dr

Step [K-1A]

This step aims at calculating the **insertion loss of the silencer including its self noise**.

- ***Bibliography (references) :***

[K1-1A] -	

- ***Comments :***

The sound power level with silencer including self noise (**Lw1** in dB ref 1E-12W) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

Lw1 = 10 * log [10^ (0.1 * (Lw0 – Di’)) + 10^ (0.1 * Lw)]

Lw being the self noise (acoustic power of flow noise in dB ref 1E-12W)

The insertion loss taking into account the self noise (**Di** in dB) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

Di = Lw0 – Lw1

In case of rectangular silencers, the obtained results are comparable with the standardized measurement: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units- Insertion loss, flow noise and total pressure loss (2004).

Aerodynamics:

- ## Steps of the computation

Step [α-1A]

All computations have been gathered in this single step for the sake of simplicity (this step aims at computing the **total pressure loss** due to the silencer).

- ***Bibliography (references) :***

[α1-1A]	
[α2-1A] -	
[α3-1A]	
[α4-1A]	
[α5-1A]	
[α6-1A]	
[α7-1A]	
[α8-1A]	

- ***Comments :***

The total pressure loss due to the silencer is computed with the hypothesis of a uniform air flow (supposed to not be rotational), taking into account the aerodynamics type upstream and downstream (*):

<table>
<tr><td>Aerodynamics type downstream</td><td>R</td><td>C</td></tr>
<tr><td rowspan="3">mounting RD</td><td rowspan="3">Rectangular</td><td>1/2 Circle</td></tr>
<tr><td>1/2 Circle for central splitters, 1/4 Circle for extreme inner lagging</td></tr>
<tr><td>1/4 Circle for extreme inner lagging</td></tr>
</table>

<table>
<tr><td>Aerodynamics type downstream</td><td>R</td><td>C</td><td>P</td></tr>
<tr><td rowspan="3">mounting RD</td><td rowspan="3">Rectangular</td><td>1/2 Circle</td><td rowspan="3">Profiled according sketch, the dotted line showing either a symmetry plane or an impervious rigid back (see fig.1A.4)</td></tr>
<tr><td>1/2 Circle for central splitters, 1/4 Circle for extreme inner lagging</td></tr>
<tr><td>1/4 Circle for extreme inner lagging</td></tr>
</table>

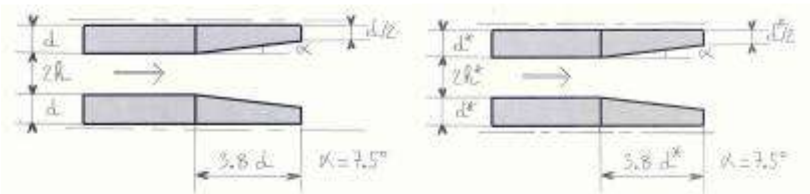


Fig.1A.4

- ✓ ***for the mounting of the worksheet CODIS-1A*** *(RD)*, the determination of the total pressure loss is done is done according various models as shown in the tables below:

Model	FRO	MEC	2081C1	**BER**	ISO
source	[α1-1A]	[α2-1A]	[α6-1A]	[α3-1A]	[α4-1A] [α7-1A]

In case of rectangular silencers, the obtained results are comparable with the standardized measurement: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units- Insertion loss, flow noise and total pressure loss.

*a safety factor has to be used (by the user) for taking into account the inhomogeneity of the inflow (see [α2-1A],[α5-1A]) leading to predictions lower than on-site values

1A. 3: How to use SILDIS

Operating conditions / security level / safety

See corresponding § in the chapter **General considerations**

For safety reasons, some cells of the original file provided to the user (as mentioned in the table below) for which input data are foreseen to be entered by the user are pre-filled with the value "1/0", among the yellow cells for which the color orange is used (*).

Worksheet	Cells
[in COALA-1A]	E13, J37
[in COSIL-1A]	D25, BD25, D37, D43, D44, D45

* something like that

** attention has to be paid to the fact that the considered sheet is not included in the worksheets listed below

Worksheets

Regarding the COmputation of DIssipative Silencers, the software SILDIS is configurated in order to allow the user to access to 4 worksheets being linked as shown in fig.1A.5 (the overview of the worksheets being shown in table below).

[in COALA-1A] → **[in COSIL-1A]** → **[in-out CODIS-1A]**

Fig. 1A.5

Concerning the worksheet [in COALA-1A]:

- a complementary set (set 0) and a rear atmosphere are displayed: they are <u>none</u> of interest for the COmputation of DIssipative Silencers (only the case of an impervious rigid back at the rear of set1 applies for the COmputation of SILencers)
- data concerning series thin plates are displayed: they are <u>none</u> of interest for the COmputation of DIssipative Silencers (not taken into account whatever the input data concerning thin plates are in worksheet in [COALA])

Worksheet	Suitable for mountings	Input data	Results
[in COALA-1A]	all	for sets, for reference spectrum	--
[in COSIL-1A]	all	particular conditions for the design of the silencer	--
[in-out CODIS-1A]	RD	condition of propagation (of sound)	indicators of performance (acoustics & Aerodynamics)

Input data, alerts and results: the key points

The best use of the software requires the knowledge of some key points in relation with:

- the **<u>input data</u>**

  See corresponding § in the chapter **General considerations**

  As far as porous media, series cloths and series perforated protections are concerned, specific data bases (libraries) (will) allow the design to be made with in-built engineering data (constants) referred to as "Usual" in the worksheets of the software. Warning: some properties of the presently referenced materials still not have been checked by reliable sources. See also report [PhRxx-015x] Collection of soundproofing constructions systems: a companion to "User's manual for the software SILDIS"

  - **<u>data base (library) for porous media</u>**
    - ✓ contents of the library: **1 possible reference of material layer**
  - **<u>data base (library) for series cloths</u>**
    - ✓ contents of the library: **1 possible reference of material layer**
  - **<u>data base (library) for series perforated protections</u>**
    - ✓ contents of the library: **1 possible reference of material layer**

- some **<u>alerts</u>** in case of input data involving a warning of the user
- the place where (and the way) some **<u>results</u>** are presented

Those key points are reviewed worksheet per worksheet hereafter: the cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA-1A]

- ***Input data :***

<table>
<tr><th>Item</th><th>Cell for input</th><th>Foreseen action</th><th colspan="2">Comment</th></tr>
<tr><td>Language</td><td>C1</td><td>for English input E, for French input F</td><td colspan="2"></td></tr>
<tr><td>Date</td><td>B3</td><td>Modification of the displayed date</td><td colspan="2"></td></tr>
<tr><td>Project</td><td>E3</td><td>Input a string</td><td colspan="2"></td></tr>
<tr><td>Title</td><td>M3</td><td>Input a string</td><td colspan="2"></td></tr>
<tr><td>Temperature</td><td>D6</td><td>Input a real number</td><td colspan="2">common value applicable to the fluid, to porous media, to series cloths, to perforated protection</td></tr>
<tr><td>Pressure</td><td>D7</td><td>Input a real positive number</td><td colspan="2">common value applicable to the fluid, to porous media, to series cloths, to perforated protection</td></tr>
<tr><td>Maximum set index imax</td><td>E13</td><td>Input an integer from 0 to 4</td><td rowspan="9">imax is the maximum set index taken into account for the computation, despite the status of the selection of the parameters related to sets with an index i> imax</td><td></td></tr>
<tr><td>Reference</td><td>G18 to K18</td><td>Select a material (in the proposed list) for each layer of interest</td><td>for CODIS only: a possible inhomogeneity in directions parallel to and perpendicular to its surface (i.e. different properties - depending on the used model - in directions x and y) is considered for the porous medium of set 1 (porous media of sets 2 to 4 being considered homogeneous)</td></tr>
<tr><td>Thickness</td><td>G37 to J37</td><td>Input a real positive number</td><td></td></tr>
<tr><td>Reference</td><td>G45 to J45</td><td>Select a reference of element (material in the proposed list) for each layer of interest</td><td></td></tr>
<tr><td>Incorporation of the series perforated protection (0/1)</td><td>G57 to J57</td><td>For NO press 0, for YES press 1</td><td></td></tr>
<tr><td>Thickness</td><td>G58 to J58</td><td>Input a real positive number</td><td>taken into account for the computation as a non zero value only if 1 in cell just above</td></tr>
<tr><td>Reference</td><td>T18 to W18</td><td>Select a reference of element (material in the proposed list) for each layer of interest</td><td></td></tr>
<tr><td>Incorporation of the series cloths (0/1)</td><td>T23 to W23</td><td>For NO input 0, for YES input 1</td><td></td></tr>
<tr><td>Thickness</td><td>T24 to W24</td><td>Input a real positive number</td><td>taken into account for the computation as a non zero value only if 1 in cell just above</td></tr>
<tr><td>Lw0 only known per 1/1 octave frequency band (0/1)</td><td>R62</td><td>For NO input 0, for YES input 1</td><td colspan="2">In case of input "0": the input data of the table below are not applicable, the next table only must be filled</td></tr>
<tr><td>Lw0</td><td>B65 to K65</td><td>Input a real positive number as requested for a 1/1 octave band sound power level</td><td colspan="2"></td></tr>
<tr><td>Lw0</td><td>B70 to P70
B73 to P73</td><td>Input a real positive number as requested for a 1/1 octave band sound power level</td><td colspan="2">In case of Lw0 only known per 1/1 octave frequency band, default values are foreseen such as
Lw0 1/3 oct = Lw0 1/1 oct - 4.8 (dB)</td></tr>
</table>

- ***Comments*** :
    - some data of the table above may not be modifiable by the user despite the displayed color of the cell
    - data of the second table (below) are not taken into account for the design of dissipative silencers

Item	Cell for input	Foreseen action	Comment
Rear atmosphere ? (0/1)	O8	For NO input 0, for YES input 1	not taken into account for CODIS
Reference	T31 to W31	Select a reference of element (material in the proposed list) for each layer of interest	
(1/2)	Y31	Select a number (in the proposed list)	select 1 (resp. 2) to get for set 0 the same plate as for set 1 (resp. set 2)
Model of losses	T36 to W36	Select a model (in the proposed list)	
Model of effective critical frequency	T37 to W37	Select a model (in the proposed list)	
Number of identical plates	T38 to X38	Input a real positive number	
Thickness	T39 to W39	Input a real positive number	taken into account for the computation as a non zero value only if a non zero value in cell just above

Note: temperature (resp. pressure) of cell D6 (resp. D7) also apply to thin plates

- data of the third table (below) are not modifiable by the user despite the displayed color of the cell

Item	Cell for input	Foreseen action	Comment
For (test) room conditions below: temperature	S48	Input a real number	common value applicable to the fluid, to porous media, to series cloths, to perforated protection
For (test) room conditions below: pressure	S49	Input a real positive number	common value applicable to the fluid, to porous media, to series cloths, to perforated protection

Worksheet [in COSIL-1A]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Limit set index **ilim**	D18	Input an integer from 1 to **imax**	**imax**- ξ ≤ **ilim** ≤ **imax** (ξ being the total number of cloths and perforated protections accounted as porous media)
Half airway h (m)	D25	Input a positive real	
Mass flow rate	D37	Input a real	A positive value is related to a direction of airflow equal to the direction of propagation of sound, a negative value is related to a direction of airflow opposite to the direction of propagation of sound
Width B (m)	D43	Input a positive real	If a particular value of N'' (resp. N''*) is wished then input the value given in O43 (resp. AQ43). If the extrapolation from mounting R to a particular mounting is wished then input the value given in R43 (resp. U43, AA43…)
Height H (m)	D44	Input a positive real	If the extrapolation to a particular mounting is wished then input the value given in R44 (resp. U44, AA44…)
Length L (m)	D45	Input a positive real	Without aerodynamics extremities
Model of reflection loss	G47	Select a model (in the proposed list)	
Model of by-pass correction	E51 to G51	Select a model (in the proposed list)	
Aerodynamics upstream	D54	Select a model (in the proposed list)	
Aerodynamics downstream	D55	Select a model (in the proposed list)	
Roughness of lining Δ (m)	AW61	Input a positive real	
Model of total pressure loss	V63	Select a model (in the proposed list)	For the COmputation of DIssipative Silencers with mountings RD
For model NF2 only B (dB)	E64	Input a positive real	For the COmputation of DIssipative Silencers with mountings RD
For model NF2 only δ (m)	G64	Input a positive real	
For all models 2081,3733, FRO only spectral correction model	G65	Select a model (in the proposed list)	Used for the interpolation of a ponderation curve (generally of secondary importance)
Model for the flow acoustic power	V65	Select a model (in the proposed list)	For the COmputation of DIssipative Silencers only

- ***Comments :***

  - some data of the table above may not be modifiable by the user despite the displayed color of the cell

Worksheets [in-out CODIS-1A]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Condition of propagation	W182	Select a model (in the proposed list)	among the possible conditions of propagation in porous medium of set 1 (for the COmputation of DIssipative Silencers **σx1/σy1**=∞, **σx1/σy1**=1, **σx1/σy1**=var.

- ***Comments :***

    - some data of the table above may not be modifiable by the user despite the displayed color of the cell

- ***Main displays of the results :***

    - **total pressure loss**: **see lines 98 to 100**

      Note: the following equation is considered for the definition of total pressure loss coefficients **ζf, ζf*, ζp**:

      $$\Delta pt = \zeta p \,.\, 0.5 \,.\, \rho \,.(Vp)^2 = \zeta f \,.\, 0.5 \,.\, \rho \,.\, (Vf)^2 = \zeta f^* \,.\, 0.5 \,.\, \rho \,.\, (Vf^*)^2$$

      Δpt: total pressure loss (Pa)
      ρ: density of fluid (kgm-3)
      Vp: speed in the area Ap (ms-1)
      Vf: speed in the area Sf (ms-1)
      Vf*: speed in the area Sf (ms-1)

- **insertion loss without flow: see line 105** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.

  Note: those results are intermediate/complementary results not equal (generally speaking) to the insertion loss with flow and self noise that the user has to use as the only reliable indicator of performance of the performance of the silencer. Those results are only displayed in order to allow the evaluation of the impact of airflow - other than self noise - by the means of a comparison with results displayed line 106.

- **insertion loss with flow without flow noise (Di'): see line 106** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.

  Note 1: those results are intermediate/complementary results not equal (generally speaking) to the insertion loss with flow and self noise that the user has to use as the only reliable indicator of performance of the performance of the silencer. Those results are only displayed in order to allow the evaluation of the impact:

  - of airflow - other than self noise - by the means of a comparison with results displayed line 105
  - of flow noise by the means of a comparison with results displayed line 162

  Note 2: since the insertion loss is predicted from the sum of the longitudinal attenuation, a bypass correction and reflection loss, the results corresponding to the different terms of the sum are also displayed in order to allow the evaluation of the impact of each one (see table below).

Term of the sum	Cells for display	Notation	Comment
longitudinal attenuation	**A108 to L127**	Da.L	curve and table of results per 1/3 octave band, per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum
by pass correction	**M108 to X127**	Dk	
reflection loss	**A129 to L148**	Dr	
insertion loss without self noise	**M129 to X148**	D'i= Da.L+ Dk+ Dr	

- **self noise (acoustic power of flow noise): see line 153** per 1/1 octave frequency band and in terms of A weighted global value

- **not A-weighted acoustic power with silencer (Lw1)**: **see line 156** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.

- **A-weighted acoustic power with silencer**: **see line 157** per 1/1 octave frequency band

- **insertion loss with flow and self noise (Di)**: **see line 162** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.

- **acoustic power without silencer (Lw0) and acoustic power with silencer including self noise (Lw1) versus frequency see lines 164 to 184 columns A to F** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.

- **insertion loss with flow without self noise (Di') and insertion loss with flow and self noise (Di) versus frequency see lines 164 to 184 columns G to L** per 1/1 octave frequency band and in terms of A weighted global value with reference to the reference acoustic power spectrum.

1A.4: Examples of computation with SILDIS

Example 1A.4.1 dissipative silencer with a rectangular cross section

Envisaged application

It is wished to compute the acoustic and aerodynamic performances of a **dissipative silencer with a rectangular cross section** (width B=1200mm [1], height H=1200mm [2], length L=1000mm [3]), having rectangular edged [4] splitters of thickness 2d such as 2d-2d'1=398.6mm [5] with a open area ratio of 55.5% [6] made of one [7] inhomogeneous in directions parallel to and perpendicular to its surface bulk absorber [8] having the reference DISP (resp. DISN) in the database for porous media of SILDIS [9] with [10] a cloth of thickness d'1=0.5/100 mm [11] having the reference DIS in the series cloths database of SILDIS [12] with a perforated protection of thickness d'1=0.7 mm [12bis] with holes diameter 3 mm spaced by a distance 5 mm with an hexagonal array, referred to as R3T5in data base [13]
It is foreseen to use the silencer with an air flow rate of 32.645 kg/s [14] at 20 °C [15] at a pressure of 101325 Pa [16].
It is decided to not take into account a limitation of the propagation loss for L>1m [17] and to not take into account the reflection loss [18].
The reference spectrum is supposed of the type "pink noise" [19] with a sound power level of 130 dB/oct [20]
It is chosen to predict the self noise of the silencer in the way described with the model referred to as 2081B [21]
It is chosen to predict the back pressure with the model referred to as FRO [22]

Input data

The input data required for the computation are listed hereafter in reference with the above data (see figures in brackets in the previous §, used as placemarks for explaining the selection below).The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA-1A] for example 1A.4.1

Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark / comment
Temperature	D6	Input a real number	20	[15]
Pressure	D7	Input a real positive number	101325	[16]
Maximum set index **imax**	E13	Input an integer from 1 to 4	1	[7]
Reference	J18 to K18	Select a reference (material in the proposed list) for each layer of interest	DISN, DISP	[8],[9]
Thickness	J37	Input a real positive number	0.19930	[5]
Reference	J45	Select a reference (material in the proposed list) for each layer of interest	R3T5	[13]
Incorporation of the series perforated protections (0/1)	J57	For NO press 0, for YES press 1	1	[13]
Thickness	J58	Input a real positive number	0.0007	[12bis]
Reference	W18	Select a material (in the proposed list) for each layer of interest	DIS	[12]
Incorporation of the series cloths (0/1)	W23	For NO input 0, for YES input 1	1	[10]
Thickness	W24	Input a real positive number	0.00005	[11]
Lw0 only known per 1/1 octave frequency band (0/1)	R62	For NO input 0, for YES input 1	1	[20]
Lw0	B65 to K65	Input a real positive number as requested for a 1/1 octave band sound power level	130	[20]

Worksheet [in COSIL-1A] for example 1A.4.1 only

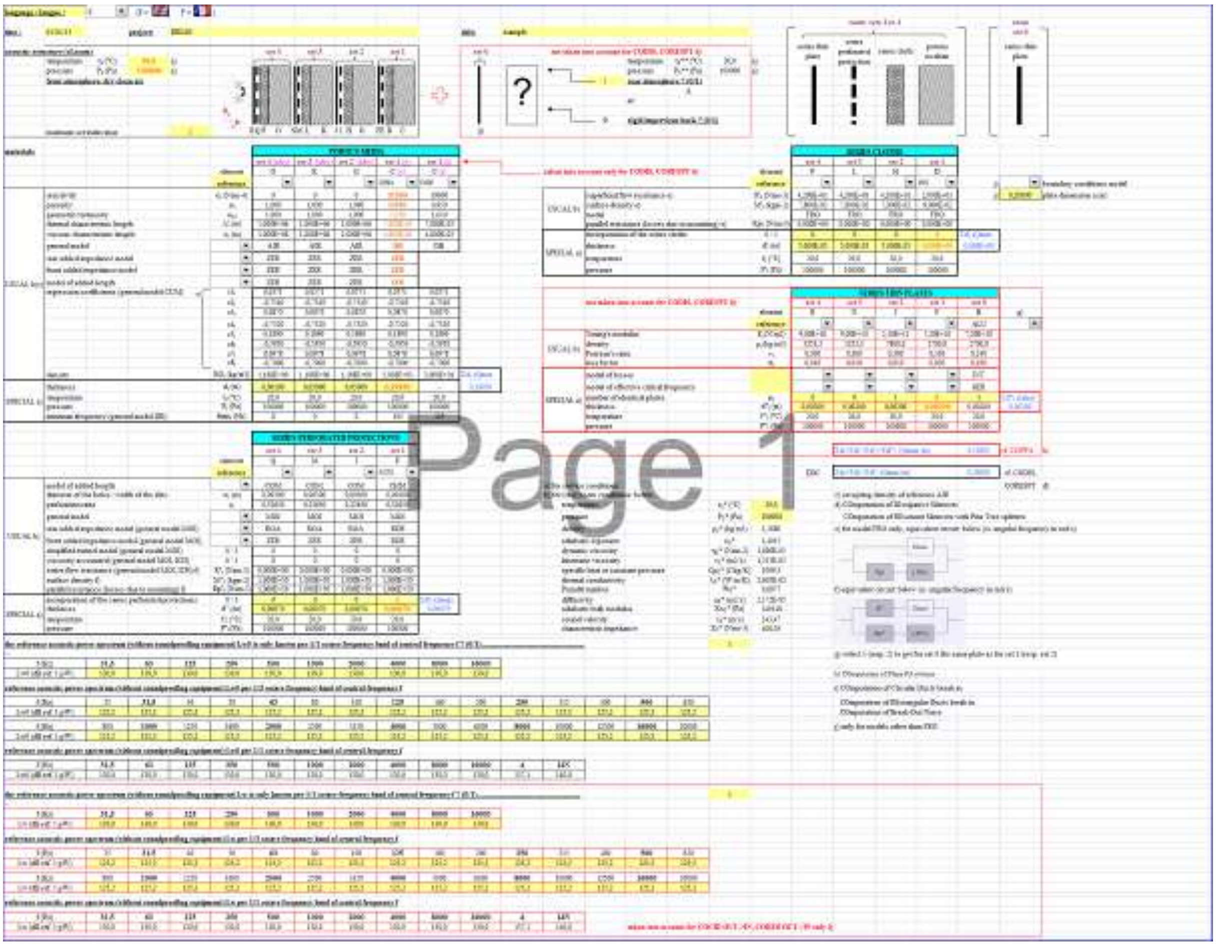
Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark
Limit set index **ilim**	D18	Input an integer from 1 to **imax**	1	[7]
Half airway	D25	Input a positive real	0.1	Based on [6]
Mass flow rate	D37	Input a real	32.645	[14]
Width B (m)	D43	Input a positive real	1.2	[1]
Height H (m)	D44	Input a positive real	1.2	[2]
Length L (m)	D45	Input a positive real	1.0	[3]
Model of reflection loss	G47	Select a model (in the proposed list)	ZER	[18]
Model of by-pass correction for L>1m	F51	Select a model (in the proposed list)	ZER	[17]
Aerodynamics upstream	D54	Select a model (in the proposed list)	R	[4]
Aerodynamics downstream	D55	Select a model (in the proposed list)	R	[4]
Model of total pressure loss	V63	Select a model (in the proposed list)	FRO	[22]
Model for the flow acoustic power	V65	Select a model (in the proposed list)	2081B	[21]

Worksheet [in-out CODIS1-1A] for example 1A.4.1 only

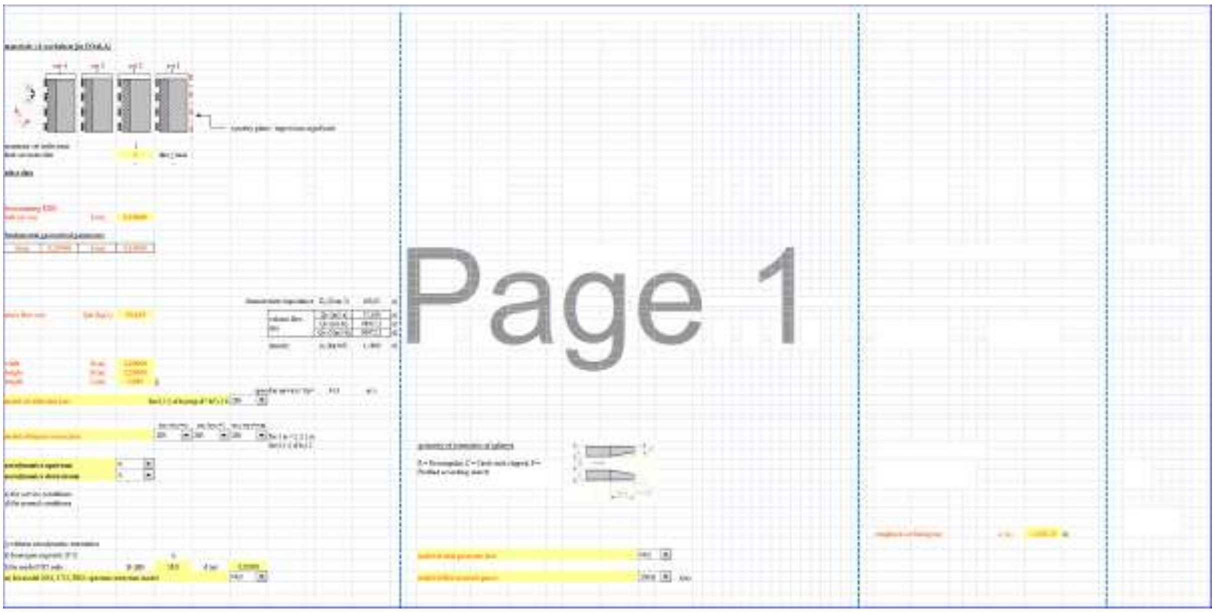
Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark
Condition of propagation	W182	Select a model (in the proposed list)	**σx1**/**σy1**=var	[8]

<u>Screenshots of the worksheets (for the example of computation)</u>

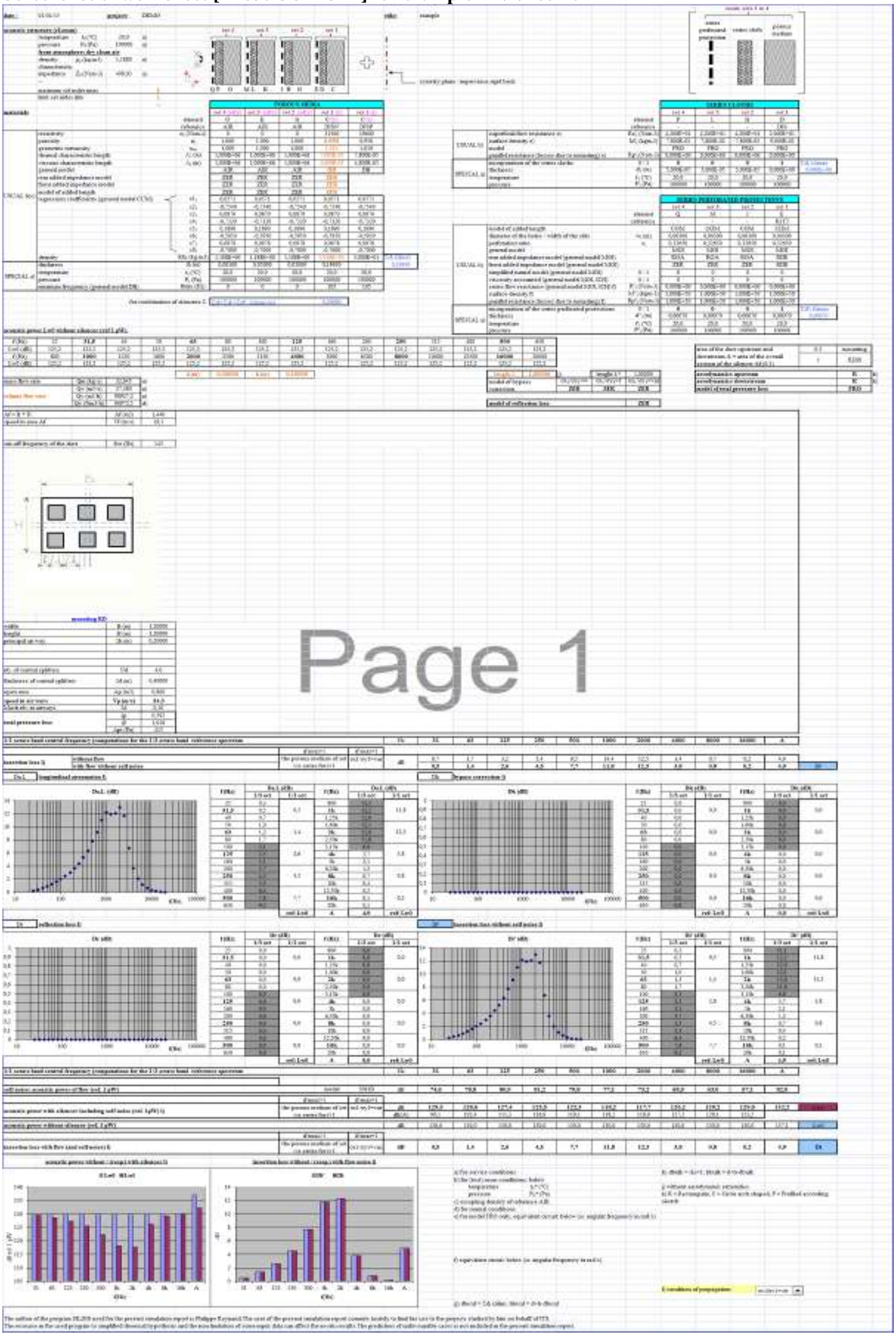
Screenshot of worksheet [in COALA-1A] for example 1A.4.1



Screenshot of worksheet [in COSIL-1A] for example 1A.4.1



Screenshot of worksheet [in-out CODIS1A] for example 1A.4.1 some



Appendix to Section 1A: list of symbols

General

f: frequency (Hz)
Lw0: sound power level without soundproofing equipment (dB ref. 1pW)
Lw1: sound power level with soundproofing equipment (dB ref. 1pW)
t: time (s)

Set of materials

ilim: limit set index
imax: maximum set index
ξ **:** total number of cloths and perforated protections accounted as porous media i.e. not accounted as series cloth (resp. series perforated protections) using electro acoustic analogie

Dry air

a: diffusivity (m^2/s)
c: (adiabatic) velocity of sound (ms^{-1})
c_p : specific heat (capacity) (at constant pressure) (J/kg/K)
C_s: adiabatic compressibility (Pa^{-1})
C_T: isothermal compressibility (Pa^{-1})
k: wave number (rad/m)
K_s: adiabatic bulk modulus (Pa)
K_T: isothermal bulk modulus (Pa)
t: temperature (°C)
P: static/atmospheric pressure (Pa)
Pr: Prandtl number
R**:** gas constant (J/kg/K)
V: volume (m^3)
Z: characteristic impedance (Nsm^{-3})

β: coefficient of thermal expansion
Γ: propagation constant (rad. m^{-1})
η : dynamical viscosity (Nsm^{-2})
λ: thermal conductivity (W/m/K)
λ: wavelength (m)
ν : kinematic viscosity **(**m^2/s)
ρ: density (kg/m3)

subscript / superscript		subscript	superscript
for normal conditions		0	N
for test (room) conditions		0	*
for service conditions	front atmosphere	0	
	rear atmosphere	0	**

Porous media

a', a'': coefficients for the expression of Γ_{an}
b', b'': coefficients for the expression of Z_{an}
c_1, c_2, c_3, c_4, c_5, c_6, c_7, c_8 : coefficients for the expression of Γ_{an} and Z_{an}
C_{seff}: adiabatic compressibility (Pa^{-1})
E: non-dimensional parameter related to frequency, flow resistivity and density of dry air
K_{seff}: adiabatic bulk modulus (Pa)
RG: (bulk) density (kg/m^3)
Z_a: characteristic impedance (Nsm^{-3})
Z_{an}: normalized characteristic impedance

α', α'': exponents for the expression of Γ_{an}
β', β'': exponents for the expression of Z_{an}
α_∞: (high frequency limit of the) tortuosity
Γ_a: propagation constant (rad.m^{-1})
Γ_{an}: normalized propagation constant
Γ_{ax}: propagation constant in the x-direction (rad.m^{-1})
Γ_{ay}: propagation constant in the y-direction (rad.m^{-1})
Λ': thermal characteristic length (m)
Λ : viscous characteristic length (m)
ρ_{eff}: effective density (kg/m^3)

ø : (open) porosity
σ: (static) air flow resistivity (=specific flow resistance) (Nsm^{-4})
σ1x: (static) air flow resistivity in the x-direction for porous medium of set 1(Nsm^{-4})
σ1y: (static) air flow resistivity in the y-direction for porous medium of set 1(Nsm^{-4})

Note: subscript i for set i except for σ1x and σ1y

Cloths

d’: thickness (m)
M’: surface density (kg/m^2)
R’: superficial flow resistance (Nsm^{-3})
Rp’: parallel resistance (losses due to mounting) (Nsm^{-3})

Note: subscript i for set i

Perforated protections

a: diameter of holes / width of slit (m)
d’’: thickness (m)
M’’: surface density (kg/m^2)
R’’: series flow resistance (Nsm^{-3})
Rp’’: parallel resistance (losses due to mounting) (Nsm^{-3})
ε: open area ratio

Note: subscript i for set i

Silencer

abulk: cf. step [F-1A] (m)
alocal: cf. step [F-1A] (m)
A : area of the duct above and below the silencer (m^2)
Af: area of the overall section of the silencer (m^2)
Ap : free area of the silencer (passage area of the airways) (m^2)
B: width for mounting RD (m)
d: overall thickness of the acoustic structure (m)
2d: for dissipative silencers, thickness of central splitters (for mounting RDdbulk: cf. step [F-1A] (m)
dlocal: cf. step [F] (m)
Da: propagation loss (dB/m)
Da.L:longitudinal attenuation (dB)
Di: insertion loss with flow and self noise (dB)
Di’: insertion loss with flow without self noise (dB) (Di’=Da*L+Dk+Dr)
Dk: limitation of the propagation loss (dB/m)
Dr: reflection loss (dB)
fco: cut-off frequency of the duct (Hz)
h=2h/2: for dissipative silencers, width of extreme air way (for mounting RD only) (m)
2h: for dissipative silencers, width of central airways (for mounting RD only)
hbulkl: cf. step [F-1A] (m)
hlocal: cf. step [F-1A] (m)
H: height for mounting RD(m)
L: length without aerodynamic extremities (m)
M: Mach number
Nd: for a dissipative silencer only number of central splitters (for mounting RD only)
Qm: mass flow rate (kg/s)
Qv: volume flow rate (m3/s or m3/h or Nm3/h)
Vf: speed of airflow in the area Af (m/s)
Vf*: speed of airflow in the area Af* (m/s)
Vp: speed of airflow in the area Ap (m/s)

Λ=d/h
ζf: total pressure loss coefficient in relation with airflow speed Vf
ζf*: total pressure loss coefficient in relation with airflow speed Vf*
ζp: total pressure loss coefficient in relation with airflow speed Vp

Miscellaneous

See also corresponding § in General considerations

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Section 2: computation of plane partitions (MODULE 2 of the software)

2.1: Introduction

Terms and definitions

For the needs of the present user's manual, the following terms and definition apply:

Partition: acoustic structure (see corresponding § in Section 0), regardless of what is on the back (atmosphere or impervious rigid back).

Plane partition: partition for which the shape of the surfaces on the one hand: facing the front atmosphere and on the other hand: at the rear are sufficiently close to a plane (for example: including corrugated plates and profiled claddings, but excluding cylindrical shells or pipes)

Sound reduction index: 10 times the decimal logarithm of the ratio of the acoustic power impinging on a partition under test to the acoustic power transmitted by the sample [see NF EN ISO 140-3 Acoustics - Measurement of sound insulation in buildings and of building elements – Part 3: Laboratory measurement of airborne sound insulation of building elements (1995)]
Rstat: with a statistic incidence (i.e. all possible incidence with an equal probability between angular limits)
Rdif: for a diffuse field

Sound absorption factor (α0**):** ratio of the acoustic power absorbed by the surface of the sample under test (no way back) to the incident acoustic power, for a plane wave at normal incidence [see ISO 10534-1 Acoustics – Determination of sound absorption coefficient and impedance in impedance tubes – Part 1: Method using standing wave ratio (1996)]

Sound absorption coefficient for a statistic incidence (αstat**):** ratio of the acoustic power absorbed by the surface of the sample to the incident acoustic power, for a plane wave with a statistic incidence (i.e. all possible incidence with an equal probability between angular limits)

Sabine's factor (αsab**):** ratio of the equivalent acoustic area of a sample to the area of the sample [see NF EN ISO 354 Acoustics – Measurement of sound absorption in a reverberation room (1993)]

Geometry

The geometry used for the design of plane partitions with the program SILDIS is shown in figure 2.1 (illustrating the case of a profiled cladding).

x: in case of an orthotropic plate, direction of highest bending stiffness (**xx:** axis about which an orthotropic plate is least stiff)
y: direction of the thickness of the partition (**yy**: axis normal to the partition surface)
z: in case of an orthotropic plate, direction of lowest bending stiffness (**zz:** axis about which an orthotropic plate is the stiffest)

Orientation: (useful in case of an orthotropic plate) the angle φ (may be displayed: **fi)** of the projection (on the surface of the acoustic structure) of the direction of propagation of the waves in the front atmosphere is considered with respect to the axis **xx** (for example, for a corrugated acoustic structure, it is with respect to the axis parallel to the corrugations as shown on the figure)

Incidence: the angle θ (may be displayed: **teta)** of the direction of propagation of the waves in the front atmosphere is considered with respect to the axis **yy**

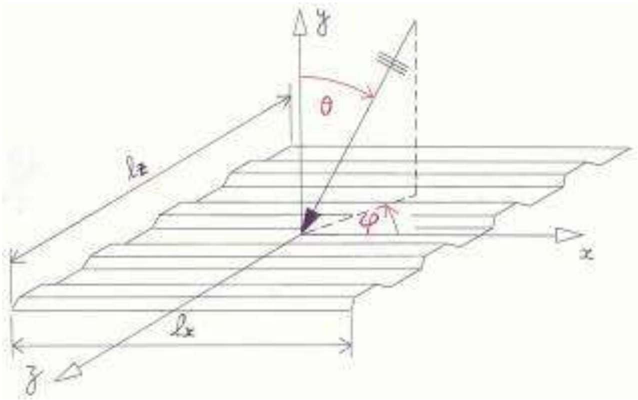


Fig. 2.1

In case of a partition surrounded by a baffle (in which the partition is symmetrically mounted), the geometry used is shown in figure 2.2

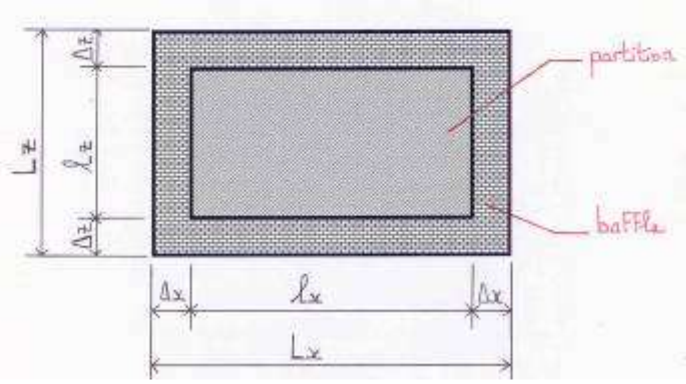


Fig. 2.2

For Lx ≠ lx the following limitation of the input data is required: Int $[\pi^{0.5} * Lx * 20000 / c_0] \leq 464$; for Lz ≠ lz the following limitation of the input data is required: Int $[\pi^{0.5} * Lz * 20000 / c_0] \leq 464$ where c_0 is the speed of sound in air (m/s). Note: For Lx ≠ lx (resp. Lz ≠ lz) the the following limitation of the input data is required for Lx (resp. Lz): 4.500 m when c_0=343.3 m/s

2.2: Scientific and technical background

The prediction of acoustic performances of plane partitions with SILDIS is founded on a scientific and technical background in relation with:

- analytical models for taking into account the properties of materials and various physical phenomena useful on the occasion of the computation
- measurement results for feeding some of those models and for allowing the necessary improvement (through correction factors) of the correlation between some calculations and on site observations

In case of an atmospheric back, the obtained results are comparable with the standardized measurement: see NF EN ISO 140-3 Acoustics - Measurement of sound insulation in buildings and of building elements – Part 3: Laboratory measurement of airborne sound insulation of building elements (1995) and (in case of rigid impervious back) see NF EN ISO 354 Acoustics – Measurement of sound absorption in a reverberation room (1993) and also ISO 10534-1 Acoustics – Determination of sound absorption coefficient and impedance in impedance tubes – Part 1: Method using standing wave ratio (1996).

2.2.1Thermodynamics and fluid dynamics:

- **Steps of the computation**

  Step [a]

  All computations have been gathered in this single step for the sake of simplicity. See corresponding § in Section 1

2.2.2 Acoustics:

- **Bloc diagram :**

  The computation scheme of plane partitions is according the bloc-diagram below (cf fig. 2.3):

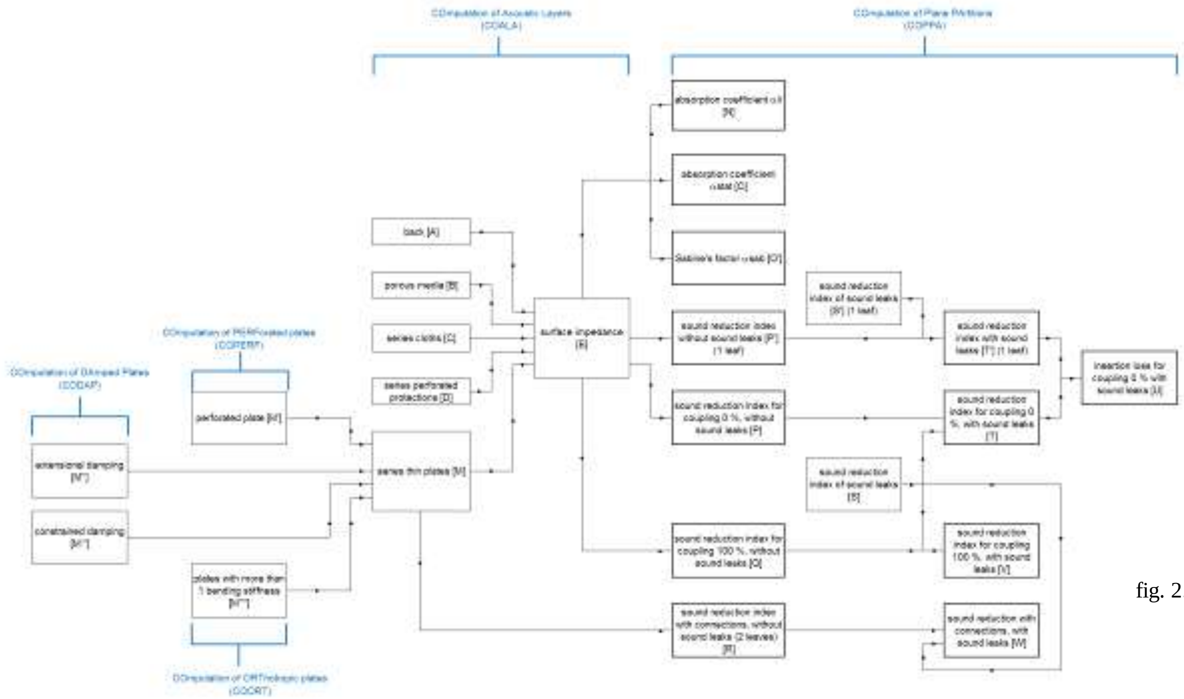


fig. 2.3

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRXX-015]

Note 2: the main steps (the steps involving a physical modeling) being referred to from [A] to [T] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

Note 3: analytical calculations are involved in steps [B] to [T] with the exception of step [R] for which empirical methods are involved

- **Steps of the computation**

Step [A]

This step aims at taking into account what is on the **back** (i.e. at the rear of the acoustic structure). See corresponding § in Section 1

- ***Bibliography (complementary sources) :***

[A2]	
[A3]	

Step [B]

This step aims at taking into account **porous media used in the acoustic structure**. See corresponding § in Section 1

Step [C]

This step aims at taking into account **series cloths** used in the acoustic structure. See corresponding § in Section 1

Step [D]

This step aims at taking into account **series perforated protections** used in the acoustic structure. See corresponding § in Section 1

Step [E]

This step aims at predicting the **surface impedance of a multilayered acoustic structure** (including porous media, series cloths and series perforated protections with a back selected in a way appropriate for the considered simulation): see corresponding § in Section 1) **including also thin plates** at the front of the series cloths (bibliography unchanged).

- ***Comments :***

It has been taken into account:

- that the most sophisticated partition of interest for the applications foreseen at ITS or elsewhere consists of a multilayer filling - from inside to outside - (see report [PhRxx-006x]):
    - 1 layer of perforated sheet (being presently with diameter of holes 3mm in a hexagonal array with a perforation rate of 32 % thickness 1.5mm)
    - 1 layer of cloth (being presently : to be précised)
    - 1 layers of porous media (being presently: to be precised)
    - 1 steel plate
    - Air
    - 1 layer of perforated sheet (being presently with diameter of holes 3mm in a hexagonal array with a perforation rate of 32 % thickness 0.8mm)
    - 1 layer of cloth (being presently : to be precised)
    - 1 layers of porous media (being presently: to be precised)
    - 1 steel plate

- the rear boundary condition for the arrangement of materials of interest for the COmputation of Plane PArtitions (being an atmospheric back for the derivation of the sound reduction index)

- possible other useful arrangements of materials (for other predictions to be done in relation with the COmputation of Acoustic LAyers, not only in the context of COmputation of Plane PArtitions)

- possible other useful rear boundary conditions for the arrangements of materials: impervious rigid back for Sabine's factor for example (also for other predictions to be done in relation with the COmputation of Acoustic LAyers, not only in the context of COmputation of Plane PArtitions)

Consequently (see figure 2.4 below showing the most sophisticated acoustic structure available under the condition – presently not fulfilled - of complete implementation of the software):

- a variable (from 1 to 4) number of sets of elements is considered for the computation, the sets being indexed from an impervious rigid back to the front (airway side): 1 to 4

- a complementary set (set 0) is used (at the rear of set 1) consisting of up to 1 thin plate (indeed 1 or several identical thin plates) backed by atmosphere or 1 backed by an impervious rigid wall, the selection being made by the user, depending on the considered application for which the computation is performed.

Remark: the set 0 has still not been 100 % implemented in the considered revision of the software (work on progress but considerable unsolved difficulties faced in relation with a computational overload)

For the total thickness of the acoustic structure **d** the following formula apply:

$$\mathbf{d} = \sum_{i=1}^{imax} \mathbf{d_i} + \sum_{i=1}^{imax} \mathbf{I'_i * d'_i} + \sum_{i=1}^{imax} \mathbf{I''_i * d''_i} + \sum_{i=0}^{imax} \mathbf{n_i * d'''_i}$$

d_i (resp. d'_i, d''_i and d'''_i) = thickness of the porous medium (resp. the series cloth, the series perforated protection and the thin plate) of set i
I'_i (resp.Id$''_i$) = 0 or 1 depending on the incorporation (or not) of the considered element of set i in the acoustic structure (omitted in the worksheets displays of the software for the sake of simplicity)
n_i= number of identical thin plates of set i (omitted in the worksheets displays of the software for the sake of simplicity)

For the total surface density of the acoustic structure **d** the following formula apply:

$$\mathbf{M} = \sum_{i=1}^{imax} \mathbf{M_i} + \sum_{i=1}^{imax} \mathbf{I'_i * M'_i} + \sum_{i=1}^{imax} \mathbf{I''_i * M''_i} + \sum_{i=0}^{imax} \mathbf{n_i * M'''_i}$$

M_i (resp. M'_i, M''_i and M'''_i) = surface density of the porous medium (resp. the series cloth, the series perforated protection and the thin plate) of set i

I'$_i$ (resp.Id''$_i$) = 0 or 1 depending on the incorporation (or not) of the considered element of set i in the acoustic structure (omitted in the worksheets displays of the software for the sake of simplicity)
n_i= number of identical thin plates of set i (omitted in the worksheets displays of the software for the sake of simplicity)

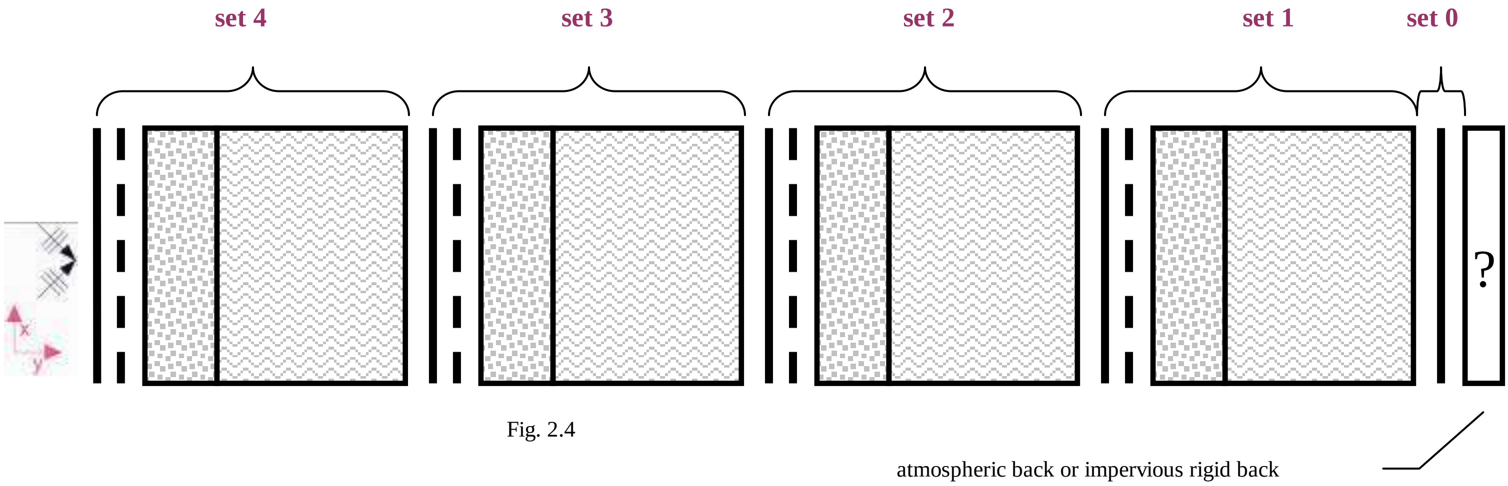


Fig. 2.4

- each set (from 1 to 4) consists (from the rear to the front) of up to 1 porous medium, up to 1 series cloth and up to 1 series perforated protection , up to 1 series thin plate (using electro-acoustic analogies): see figure 2.5 below.

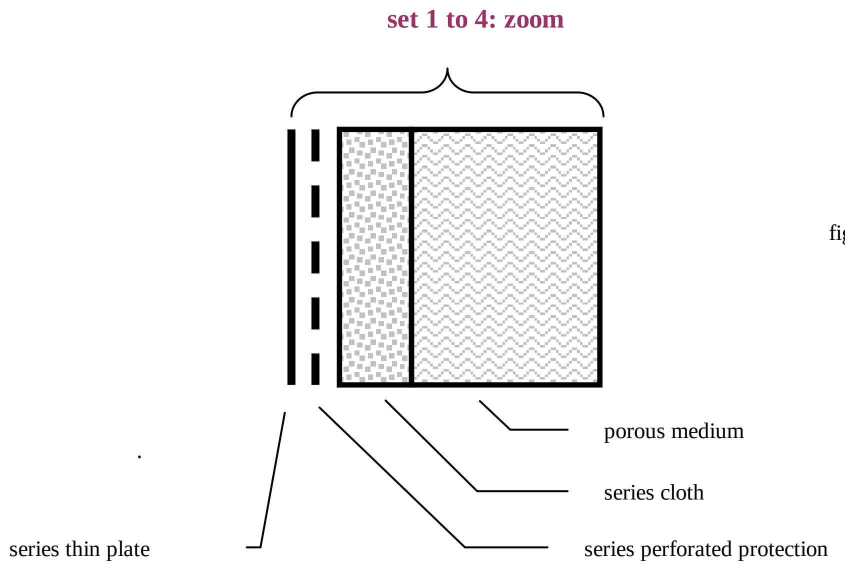


fig. 2.5

- each thin plate can be either profiled (when monolithic) or with an extensional damping or with a constrained damping (see fig. 2.6 and 2.7)
- the surface impedance of the acoustic structure with an impervious rigid back or with an atmospheric back is calculated above the set **imax**: the COmputation of the Plane PArtitions is performed for an acoustic structure (with an impervious rigid back or with an atmospheric back) including sets from **0** to **imax (with 0 ≤ imax ≤ 4)**

Note: for the considered version of SILDIS, calculations with the routine COPPA are possible for **imax** = 0 or for **imax** =1or for **imax** = 2

The less complicated models available for taking into account the physical properties of a porous medium are based on the hypothesis of homogeneity in directions parallel to and perpendicular to the surface of the material (i.e. same properties in directions **x**, **y** and **z**). Although some porous media (including some stone wools, some glass wools) are known to be non homogeneous in directions parallel to and perpendicular to the surface of the material having (in particular) an airflow resistivity normal to laminae of fibers $\boldsymbol{\sigma_N}$ and an airflow resistivity parallel to laminae of fibers $\boldsymbol{\sigma_P}$ that can notably differ (with $\boldsymbol{\sigma_P}$ reaching only 0.5*$\boldsymbol{\sigma_N}$ sometimes), no possible inhomogeneity of porous media in directions parallel to and perpendicular to its surface (i.e. no different properties - depending on the used model - in directions **x** and **y**) is considered (for the routine COmputation of Plane PArtitions).

Note 1: each layer is assumed to not be glued to another

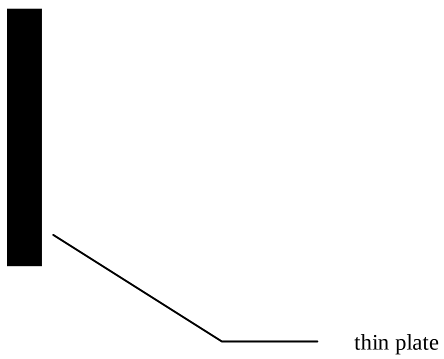
Note 2: concerning the perforated protection of the set **i**, the porous medium taken into account with the models of added impedance ROA and RDE is:

- at the rear: the porous medium of set **i**
- at the front: the porous medium of set **i+1** if **i<4** (<u>even if **i+1>imax**</u>: the selection of a reference different of AIR for the porous media of set **i** such as **i>imax** is highly discouraged) or the front atmosphere if **i=4**

Note 3: the use in practical cases (and the corresponding prediction of performance) of a perforated protection in contact with something else than a porous medium (that can be air at the front or a thin wire mesh spacer at the rear in some cases) is highly discouraged

Step [M]

This steps aims at taking into account **series thin plates** used in the acoustic structure.



- ***<u>Bibliography (references) :</u>***

[M1]	
[M2]	
[M3] -	
[M4] -	
[M5] -	
[M6] -	
[M7] -	
[M8] -	
[M9] -	

- ***<u>Comments :</u>***

The following governing equation is considered (with notations adapted from various sources: will be specified on the occasion of a future revision of this user's manual):

$$D_{11} \frac{\partial^4 w}{\partial x^4} + 2\,(D_{12} + 2D_{66}) \frac{\partial^4 w}{\partial x^2 \partial z^2} + D_{22} \frac{\partial^4 w}{\partial z^4} + M''' \frac{\partial^2 w}{\partial t^2} = p\,(x, z, t)$$

where

M''': surface density (kg/m2)
p: pressure (Pa)
t: time (s)
w: lateral (transverse) displacement (m)

and where

the bending stiffnesses Dij (i and j varying from 1 to 2) (Nm) can be expressed as:

$D_{11} = D'x = D$
$2\,(D_{12} + 2D_{66}) = 2\,D'xz = 2\,H = 2D$, where $= D'xz = (D'x\,D'z)^{0.5} = D$
$D_{22} = D'z = D$

The loss factor of plates η is computed according various models as shown in the table below:

model	**INT**	TOT
source	η of the material	[M5]

When used, the frequency corresponding to the mode (1,1) of thin plates f_{11} (may be displayed f11) is computed according various models as shown in the table below:

model	HAN	**HEA**
source	[M4]	[M6]

The critical frequency fc is derived as:

$$fc = \frac{c^2}{2\pi} \left[\frac{M'''}{D} \right]^{0.5}$$

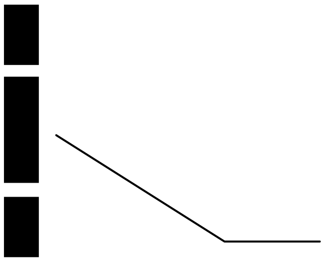
The effective critical frequency fceff (applicable in case of a thickness of the plate not sufficiently small for allowing to consider the plate as a thin plate) is computed according various models as shown in the table below:

model	GER	NF	**NAT**
source	[M7], [M8]	[M9]	fceff=fc

Step [M']

This step, being a complementary feature associated with step [M], aims at calculating the properties of **series perforated plates** in the acoustic structure.

This steps aims at taking into account **series thin plates** used in the acoustic structure.



In order to include the calculations in the general layout of the program, an equivalent series thin plate is considered, referenced PERFO, available in the list of thin plates of the worksheet [in COALA], for which the corresponding parameters are first derived from the input data of the layer, by the use (before using the worksheet [in COALA]) of a complementary worksheet referenced [in-out COPERF] (COmputation of PERForated plates).

- ***Bibliography (references) :***

[M'1]	

- ***Comments :***

The Young's modulus of the equivalent plate (depending on open area ratio ε) is computed according various models as shown in the table below

model	MEC
source	[M'1]

The density of the equivalent plate (depending on open area ratio ε) is computed as for a monolithic plate of same surface density and of same thickness.

The Poisson's ratio of the equivalent plate is set to the Poisson's ratio of the (thin) base plate.
The loss factor of the equivalent plate is set to the loss factor of the base (thin) plate.

Step [M'']

This step, being a complementary feature associated with step [M], aims at calculating the properties of damped plates made of a (thin) base plate and of an unconstrained layer of damping material in the acoustic structure (**extensional damping**) as shown of figure 2.8 below

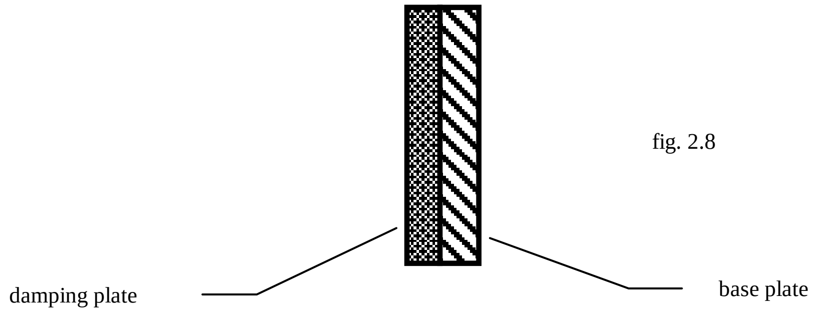


fig. 2.8

In order to include the calculations in the general layout of the program, an equivalent series thin plate (composite) is considered, referenced 2-PLY, available in the list of thin plates of the worksheet [in COALA], for which the corresponding parameters are first derived from the input data of each layer of the composite, by the use (before using the worksheet [in COALA]) of a complementary worksheet referenced [in-out CODAP] (COmputation of DAmped Plates).

- ***Bibliography (references) :***

[M''1]	
[M''2] -	
[M''3] -	
[M''4]	
[M''5]	
[M''6]	
[M''7] -	

- ***Comments :***

The Young's modulus and the loss factor of the equivalent plate are computed according various models as shown in the table below:

model	BER	MOI	AB
source	[M''1] [M''2] [M''4]	[M''3] [M''4]	[M''7]

The density of the equivalent plate is computed as for a monolithic plate of same surface density and of same total thickness (the sum of the thicknesses of the 2 layers of the composite - as displayed in worksheet [in-out CODAP] - is required as an input in the worksheet [in COALA] for the thickness of the thin plate referenced 2-PLY).

The Poisson's ratio of the equivalent plate is set to the Poisson's ratio of the (thin) base plate. The use of results of computations involving damping materials with Poisson's ratio not sufficiently close of the Poisson's ratio of the (thin) base plate is discouraged.

Step [M''']

This step, being a complementary feature associated with step [M], aims at calculating the properties of damped plates made of a 1st thin plate (base plate), a damping material and a 2nd thin plate (constraining layer) in the acoustic structure (**constrained damping)** as shown of figure 2.9 below

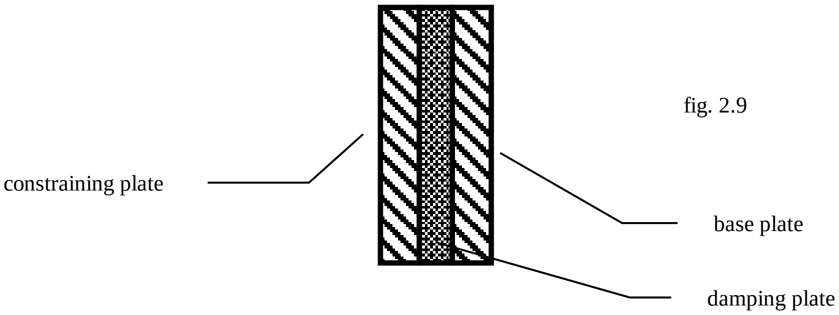


fig. 2.9

In order to include the calculations in the general layout of the program, an equivalent series thin plate (composite) is considered, referenced 3-PLY, available in the list of thin plates of the worksheet [in COALA], for which the corresponding parameters are first derived from the input data of each layer of the composite, by the use (before using the worksheet [in COALA]) of a complementary worksheet referenced [in-out CODAP] (COmputation of DAmped Plates).

At the date of writing of the present user's manual, it has not been checked in a satisfying way the accuracy of the software for the computation of the performances of sandwich panels with a thickness of the core much greater than the thickness of the laminates and/or with any extensional stiffness.

At the date of writing of the present user's manual, it has not been checked in a satisfying way the accuracy of the software for all the possible models involved in the step [P'] when the reference 3-PLY is used for the plate.

- ***Bibliography (references) :***

[M'''1]	
[M'''2] -	
[M'''3] -	
[M'''4]	
[M'''5]	
[M'''6]	
[M'''7] -	

- ***Comments :***

The Young's modulus and the loss factor of the equivalent plate referenced 3-PLY are computed according various models as shown in the table below:

model	BER	MOI	MAX
source	[M'''1] [M'''2]	[M'''3] [M'''4]	(*)

*combining models BER and MOI

The density of the equivalent plate is computed as for a monolithic plate of same surface density and of same total thickness (the sum of the thicknesses of the 3 layers of the composite - as displayed in worksheet [in-out CODAP] - is required as an input in the worksheet [in COALA] for the thickness of the thin plate referenced 3-PLY).

The Poisson's ratio of the equivalent plate is set to the Poisson's ratio of the base (thin) plate. The use of results of computations involving damping materials with Poisson's ratio not sufficiently close of the Poisson's ratio of the base (thin) plate is discouraged.

Step [M'''']

This step, being a complementary feature associated with step [M], aims at calculating the properties of **series orthotropic plates** in the acoustic structure (i.e. plates for which the bending stiffness is dependent upon the direction of wave propagation).

In order to include the calculations in the general layout of the program, an equivalent series thin plate is considered, referenced ORTHO, available in the list of thin plates of the worksheet [in COALA], for which the corresponding parameters are first derived from the input data of the layer, by the use (before using the worksheet [in COALA]) of a complementary worksheet referenced [in-out COORT] (COmputation of ORThotropic plates).

At the date of writing of the present user's manual, it has not been checked in a satisfying way the accuracy of the software for models different of the model INT involved in the step [P'] when the reference ORTHO is used for the plate.

- ***Bibliography (references) :***

[M''''1]	
[M''''2] -	
[M''''3] -	
[M''''4]	
[M''''5] -	
[M''''6]	
[M''''7] -	
[M''''8] -	

- ***Comments :***

The bending stiffness **D'x** (**D'zz**) in the direction **x** of highest bending stiffness of the plate (about the **zz**-axis about which the panel is the stiffest) and the bending stiffness **D'z** (**D'xx**) in the direction **z** of lowest bending stiffness of the plate (about the **xx**-axis about which the panel is the least stiff), of the equivalent plate referenced ORTHO are computed according various models as shown in the table below (cf. fig 2.10):

model	COR	RIB	CLA	MOI
source	[M''''1]	[M''''1]	(*)	(**)

*For the model CLA, the bending stiffness are computed according various models as shown in the table below :

model	SAY	HAN
source	[M''''2], [M''''3]	[M''''6], [M''''7]

**D'x (D'zz) and D'z (D'xx) are input data

model COR

model RIB

model CLA

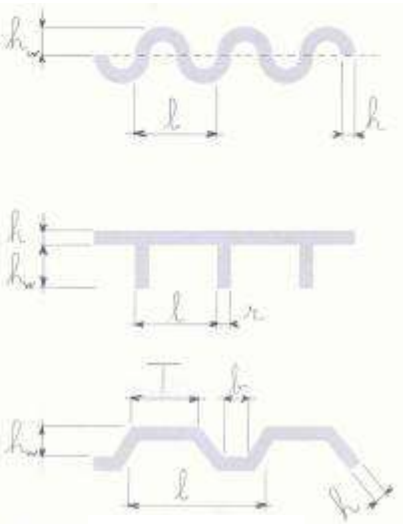


Fig. 2.10

The following governing equation is considered (with notations adapted from various sources: will be specified on the occasion of a future revision of this user's manual):

$$D_{11}\frac{\partial^4 w}{\partial x^4} + 2\,(D_{12} + 2D_{66})\frac{\partial^4 w}{\partial x^2 \partial z^2} + D_{22}\frac{\partial^4 w}{\partial z^4} + M'''\frac{\partial^2 w}{\partial t^2} = p\,(x, z, t)$$

where

M''': surface density (kg/m2)
p: pressure (Pa)
t: time (s)
w: lateral (transverse) displacement (m)

and where

the bending stiffnesses Dij (i and j varying from 1 to 2) (Nm) can be expressed as:

$D_{11} = D'x$
$2\ (D_{12} + 2D_{66}) = 2\ D'xz = 2\ H$, where $= D'xz = (D'x\ D'z)^{0.5}$ with the exception of the model MOI where D'xz is an input data
$D_{22} = D'z$

When used, the frequency corresponding to the mode (1,1) of thin plates f_{11} (may be displayed f11) is computed according various models as shown in the table below:

model	HAN	**HEA**
source	[M''''6]	[M''''8]

The Young's modulus of the equivalent plate referenced ORTHO is set to the Young's modulus of the base (thin) plate.

The density of the equivalent plate is computed as for a monolithic plate of same surface density and of same total thickness (the overall thicknesses of the plate - as displayed in worksheet [in-out COORT] - is required as an input in the worksheet [in COALA] for the thickness of the thin plate referenced ORTHO).

The Poisson's ratio of the equivalent plate is set to the Poisson's ratio of the base (thin) plate.

The loss factor of the equivalent plate is set to the loss factor of the base (thin) plate.

The lowest critical frequency fcx is derived as:

$$fcx = \frac{c^2}{2\pi} \left[\frac{M'''}{D'x} \right]^{0.5}$$

The upper critical frequency fcz is derived as:

$$fcz = \frac{c^2}{2\pi} \left[\frac{M'''}{D'z} \right]^{0.5}$$

Step [N]

This steps aims at calculating the **sound absorption coefficient at normal incidence** of the acoustic structure assumed to be locally reacting

- ***Bibliography (references) :***

[N1]	
[N2]	
[N3]	

- ***Comments :***

The sound absorption coefficient at normal incidence derived by the means of the present step is referred to as α**0** (may be displayed: **alpha 0**).

- ***Remarks in relation with the displayed results:***

In case of rigid impervious back, at the room conditions of temperature and pressure, the displayed results in terms of values per 1/3 octave frequency band (computed from 1/21 octave frequency band values) are comparable with the standardized measurement: see standard ISO 10534-1 Acoustics – Determination of sound absorption coefficient and impedance in impedance tubes – Part 1: Method using standing wave ratio.

The values per 1/1 octave frequency band are obtained with SILDIS by averaging the results per 1/3 octave band

Step [O]

This steps aims at calculating the **sound absorption coefficient for a statistic incidence** of the acoustic structure

- ***Bibliography (references) :***

[O1]	
[O2]	
[O3]	
[O4] -	
[O5] -	
[O6]	

- ***Comments :***

The sound absorption coefficient for a statistic incidence derived by the means of the present step is referred to as **αstat** (may be displayed: **alpha stat**).

- ***Remarks in relation with the angular integration*** (see § Geometry in Section 2)

The sound absorption coefficient for a statistic incidence is calculated (per frequency band) by angular integration according to the generalized (customized) formula below (see notations farther):

$$\alpha stat = \frac{1}{N} \sum_{i=1}^{N} \left(\frac{\displaystyle\int_{\theta min}^{\min(\theta max,\, \theta L)} \alpha(\varphi,\theta)*\cos(\theta)*\sin(\theta)*d\theta}{\displaystyle\int_{\theta min}^{\min(\theta max,\, \theta L)} \cos(\theta)*\sin(\theta)*d\theta} \right)$$

with the notable exception of the model DAV where the denominator is replaced by 0.5

- ***with respect to the orientation (angle φ):*** the integration is performed from **φmin** to **φmax** as selected by the user (in order to match field considerations) in a proposed list (for the present version of the program, angles from 5.625 to 84.375° with a step of 11.25° i.e. **N**=8 angles)

  Recall: orientation (angle φ) is of interest in case of an orthotropic plate included in the acoustic structure

- ***regarding the incidence (angle θ):*** the integration is performed from **θmin** to min (**θmax, θL)**

  - **θmin** and **θmax** are selected by the user (in order to match field considerations) in a proposed list (for the present version of the program, angles from 0 to 89.375° with a step of 1.25° i.e. 73 angles)

  - **θL** is taken into account according various models as shown in the table below:

model	90°	DAV	MOI
source	(*)	[O4] [O5]	[O4] [O5] [O6]

*θL = 90°

Accordingly:

- ***with respect to the orientation (angle φ):***

  ✓ for a simulation between 2 limiting angles of incidence (to choose), the user will input (by the means of the proposed lists) a value for **φmin** and a value for **φmax**

- ✓ for a simulation of a diffuse incidence (<u>with respect to the orientation angle φ),</u> the user will input (by the means of the proposed lists) 5.625° for **φmin** and 84.375° for **φmax**

- ***regarding the incidence (angle θ):***

  - ✓ for a simulation between 2 limiting angles of incidence (to choose), without other consideration, the user will input (by the means of the proposed lists):

    - ➢ a value for **θmin** and a value for **θmax**
    - ➢ the model for **θL:** 90°

  - ✓ for a simulation of a field (diffuse ?) incidence (<u>with respect to the incidence angle θ</u>)

    - ➢ using the (classical) approach consisting (for a partition of undefined extent) in using a unique limiting value of the angle of incidence (78°, 80°, 85° … in any case below 90° in order to reduce the discrepancies between prediction and measurement results especially at low frequency), the user will input (by the means of the proposed lists):

      - 0° for **θmin**
      - the closer (to the wished limiting angle) value for **θmax**
      - the model for **θL:** 90°

    - ➢ using the "pure" approach basing the model referred to as "DAV" (taking into account the dimensions of the partition), the user will input (by the means of the proposed lists):
      - 0° for **θmin**
      - 90° for **θmax** and
      - the model for **θL:** DAV

    - ➢ preferring not replacing by 0.5 the denominator of the formula above, but being interested by the approach basing the model referred to as "DAV" the user will input (by the means of the proposed lists):

      - 0° for **θmin**
      - 90° for **θmax** and
      - the model for **θL:** MOI

○ ***<u>Remarks in relation with the displayed results:</u>***

In case of rigid impervious back, at the room conditions of temperature and pressure and with an appropriate selection of values of limiting angles of integration the displayed result(s):

- in terms of values per 1/3 octave frequency band (computed from 1/21 octave frequency band values) and in term of values per 1/1 octave frequency band are comparable with the standardized measurement: see standard NF EN ISO 354 Acoustics – Measurement of sound absorption in a reverberation room.

- in terms of the unique index αw is comparable with the standardized measurement: see standard NF EN ISO 11654 Acoustics – Sound absorbers for use in buildings – Rating of sound absorption.

Step [O']

This step, being a complementary feature associated with step [O], aims at calculating the **Sabine's factor** of the acoustic structure

○ ***<u>Bibliography (references) :</u>***

[O'1]	

○ ***<u>Comments :</u>***

The sound absorption coefficient derived by the means of the present step is referred to as **αsab** (may be displayed: **alpha sab**).

When **alpha stat** reaches 1**, αsab** is set to an (upper) (finite) limiting value being chosen by the user for the considered version of the software

○ ***<u>Remarks in relation with the angular integration</u>*** (see § Geometry in Section 2)

The Sabine's factor is derived (per frequency band) from the sound absorption coefficient for a statistic incidence: attention has to be paid to angular limits of integration appropriate for a diffuse field (see corresponding § at step [O])

- ***Remarks in relation with the displayed results:***

  see corresponding § at step [O]

  Note: in case of rigid impervious back only makes the results displayed for **αsab** sense

Step [P]

This steps aims at calculating the **sound reduction index for coupling 0 % without sound leaks**

- ***Bibliography (references) :***

[P1]	
[P2]	
[P3] -	
[P4] -	
[P5] -	
[P6]	

- ***Comments:***

  The transmission loss for a statistic incidence derived by the means of the present step is referred to as **R stat = -10log(τstat)** where **τstat** is the transmission factor for a statistic incidence

- ***Remarks in relation with the angular integration*** (see § Geometry in Section 2)

  The transmission factor for a statistic incidence is calculated (per frequency band) by angular integration according to the generalized (customized) formula below (see notations farther):

$$\tau stat = \frac{1}{N}\sum_{i=1}^{N}\left(\frac{\int_{\theta min}^{\min(\theta max,\ \theta L)} \tau(\varphi,\theta)\cos(\theta)\sin(\theta)\,d\theta}{\int_{\theta min}^{\min(\theta max,\ \theta L)} \cos(\theta)\sin(\theta)\,d\theta}\right)$$

with the notable exception of the model DAV where the denominator is replaced by 0.5

- ***with respect to the orientation (angle φ):*** the integration is performed from **φmin** to **φmax** as selected by the user (in order to match field considerations) in a proposed list (for the present version of the program, angles from 5.625 to 84.375° with a step of 11.25° i.e. **N**=8 angles)

  Recall: orientation (angle **φ**) is of interest in case of an orthotropic plate included in the acoustic structure

- ***regarding the incidence (angle θ):*** the integration is performed from **θmin** to min (**θmax, θL)**

  - **θmin** and **θmax** are selected by the user (in order to match field considerations) in a proposed list (for the present version of the program, angles from 0 to 89.375° with a step of 1.25° i.e. 73 angles)
  - **θL** is taken into account according various models as shown in the table below:

model	90°	DAV	MOI
source	(*)	[O4] [O5]	[O4] [O5] [O6]

*$\boldsymbol{\theta L}$ = 90°

Accordingly:

- ***with respect to the orientation (angle φ):***

  - ✓ for a simulation between 2 limiting angles of incidence (to choose), the user will input (by the means of the proposed lists) a value for **φmin** and a value for **φmax**

  - ✓ for a simulation of a diffuse incidence (with respect to the orientation angle φ), the user will input (by the means of the proposed lists) 5.625° for **φmin** and 84.375° for **φmax**

- ***regarding the incidence (angle θ):***

  - ✓ for a simulation between 2 limiting angles of incidence (to choose), without other consideration, the user will input (by the means of the proposed lists):

    - ➢ a value for **θmin** and a value for **θmax**
    - ➢ the model for **θL:** 90°

  - ✓ for a simulation of a field (diffuse ?) incidence (with respect to the incidence angle θ)

    - ➢ using the (classical) approach consisting (for a partition of undefined extent) in using a unique limiting value of the angle of incidence (78°, 80°, 85° … in any case below 90° in order to reduce the discrepancies between prediction and measurement results especially at low frequency), the user will input (by the means of the proposed lists):

      - 0° for **θmin**
      - the closer (to the wished limiting angle) value for **θmax**
      - the model for **θL:** 90°

    - ➢ using the "pure" approach basing the model referred to as "DAV" (taking into account the dimensions of the partition), the user will input (by the means of the proposed lists):
      - 0° for **θmin**
      - 90° for **θmax** and
      - the model for **θL:** DAV

    - ➢ preferring not replacing by 0.5 the denominator of the formula above, but being interested by the approach basing the model referred to as "DAV" the user will input (by the means of the proposed lists):

      - 0° for **θmin**
      - 90° for **θmax** and
      - the model for **θL:** MOI

- ***Remarks in relation with the displayed results:***

The sound reduction index is computed at frequency steps of 1/3 octave (from 1/21 octave frequency band values) and then calculated per 1/1 octave frequency band for a reference acoustic power spectrum **Lw0** in dB ref 1E-12W).

In case of a rear atmosphere at the room conditions of temperature and pressure, the obtained (with an appropriate selection of values of limiting angles of integration) result(s):

- in terms of sound reduction index per 1/3 octave frequency band are comparable with the standardized measurement: see NF EN ISO 10140-2 Acoustics. Laboratory measurement of sound insulation of building elements. Measurement of airborne sound insulation

- in terms of sound reduction index per 1/1 octave frequency band are comparable with the same standard when obtained with SILDIS by the use of a pink power spectrum for Lw0.

- in terms of the unique index Rw is comparable with the standardized measurement: see standard NF EN ISO 717-1 Acoustics – Rating of sound insulation in buildings and of building elements – Part 1: Airborne sound insulation.

Step [P']

This step, being a complementary feature associated with step [P], aims at calculating the **sound reduction index of a single-leaf (rectangular) (plane) partition** (thin plate 0) **with sound leaks**, allowing an extended integration of various parameters (1 plate alone such as those of set 0, regardless of the selected quantity of such plates for set 0, regardless of the selected quantities of other elements, and with atmosphere at the front and at the rear regardless of the selected input data)

- ***Bibliography (references) :***

[P'1] -	
[P'2] -	
[P'3] -	
[P'4]	
[P'5] -	
[P'6] -	
[P'7] -	
[P'8] -	
[P'9] -	
[P'10] -	
[P'11]	
[P'12]	
[P'13] -	
[P'14] -	
[P'15] -	

- ***Comments :***

  - when used, the boundary conditions are taken into account according various models as shown in the table below:

model	SSE	CE	MID
condition	Simply Supported Edges	Clamped Edges	MIDSay between SSE and CE

  - when used, the free bending waves radiation ratio σrad is computed according various models as shown in the table below:

model	MAI	NF
source	[P'1][P'2] [P'3] [P'4] [P'5] (*)	[P'1][P'2] [P'3] [P'4] [P'5]

*although not mentioned in references [P'1 and [P'2], considerations in relation with the eigen frequency corresponding to the mode (1,1) of the plate (f_{11}) are also considered. The models MAI and NF differ only by the result obtained in the area of the critical frequency.

  - when used, the transmission factor for normal incidence TO is computed either with a simplified model (1/TO proportional to the frequency) or not simplified

  - when used, the loss factor η is taken into account in the way described for step [M]

  - the transmission factor is computed according various models taking into account (resp. taking not into account) various parameters as shown in the table below:

general model		SHA(*)	**MOI**
source		[P'6]	(**)
parameters	forced transmission	yes	yes/no
	resonant transmission	no	yes/no
	partition in a baffle / niche effect	no	yes/no

*not appropriate for computations with the plate referenced 3-PLY **see below

- when used, the general model MOI allows to compute the sound reduction index R as a function of frequency f as follows:

  - *below the critical frequency fc :*

    - ✓ for f sufficiently below fc, the forced transmission factor τforced is derived according various models as shown in the table below:

model	4TO	3TO	INT	SEW	BAL	DAV
source	[P'7]	[P'5]	[P'5] (*)	[P'8]	[P'9]	[P'6] [P'10]

model	JOS	GER	NF	NI1 (**)	NI2 (**)	ZER
source	[P'11] [P'12]	[P'13]	[P'3]	[P'14]	[P'15]	τforced=0

* see step [M] (in case of a non "pure" thin plate see also steps [M'] to [M'''], see remarks in relation with the angular integration: below) ** the use of this model is highly discouraged if the same choice of model is not made for resonant transmission

    - ✓ for f sufficiently below fc, the resonant transmission factor τres is derived according various models as shown in the table below:

model	SEA	JOS	NF	NI1	NI2	ZER
source	[P'4] [P'5]	[P'11] [P'12]	[P'3]	[P'14] (*)	[P'15] (*)	τres=0

* the use of this model is highly discouraged if the same choice of model is not made for forced transmission

    - ✓ for f ≈ fc the transmission factor is derived (for a frequency range chosen by the user in terms of a number of 1/3 of octave below fc) according various models as shown in the table below:

model	JOS	NF	NAT
source	[P'11] [P'12]	[P'3]	(*)

* the transmission factor is derived as for the general case f < fc

  - *at and above the critical frequency fc:*

    - ✓ for f sufficiently above fc the transmission factor τ is derived according various models as shown in the table below:

model	INT	SEA	CRE	JOS	NF	NIL
source	[P'5](*)	[P'2] [P'5]	[P'6]	[P'11]	[P'3]	[P'14] [P'15]

* see step [M] (in case of a non "pure" thin plate see also steps [M'] to [M'''], see remarks in relation with the direction of the waves impinging the partition: below)

✓ for f ≈ fc the transmission factor is derived (for a frequency range chosen by the user in terms of a number of 1/3 of octave above fc) according various models as shown in the table below:

model	JOS	NF	NI2	NAT
source	[P'11] [P'12]	[P'3]	[P'15] (*)	(**)

* to be used only with model NI2 for forced and resonant transmission, and with model NIL for transmission above fc ** the transmission factor is derived as for the general case f ≥ fc

➢ *in order to retrieve some (not always comprehensive) presentations given in various bibliographic sources with the general model MOI:*

source	models	[P'2]	[P'3]	[P'5]	[P'8]	[P'9]
boundary conditions		SSE/CE	SSE/CE	SSE/CE	?	-
radiation ratio (of free bending waves)		MAI	NF	MAI	?	-
simplified transmission factor for normal incidence		yes	yes	no/yes	yes	yes
for f < fc	model of forced transmission	ZER	NF	INT	SEW	BAL
	model of resonant transmission	SEA	NF	SEA	SEA?	ZER
for f > fc	model of transmission	SEA	NF	INT/SEA	SEA?	CRE

source	models	[P'10]	[P'11]	[P'13]	[P'14]	[P'15]
boundary conditions		-	SSE/CE	SSE/CE	SSE/CE	SSE/CE
radiation ratio (of free bending waves)		-	?	?	-	-
simplified transmission factor for normal incidence		no	yes	no/yes	yes	yes
for f < fc	model of forced transmission	DAV	JOS	GER	NI1	NI2
	model of resonant transmission	ZER	JOS	JOS	NI1	NI2
for f > fc	model of transmission	CRE	JOS	JOS	NIL	NIL

➢ *in order to retrieve the results of step [P] (with other appropriate input data :*

source	models	step [P]
boundary conditions		-
radiation ratio (of free bending waves)		-
simplified transmission factor for normal incidence		no
for f < fc	model of forced transmission	INT
	model of resonant transmission	0
for f > fc	model of transmission	INT

The sound reduction index derived by the means of the present step is referred to as **R dif** (assuming a diffuse field).

In case of use of the model INT, attention has to be paid to an appropriate selection of limiting angles for the angular integration in order to match field considerations.

- ***Remarks in relation with the angular integration:***

  in case of use of the model INT: see corresponding § at step [P]

- ***Remarks in relation with the displayed results:***

  see corresponding § at step [P]

Step [Q]

This steps aims at calculating the **sound reduction index for coupling 100 % without sound leaks**

- ***Bibliography (references) :***

  See comments below

- ***Comments :***

  The approach of step [P] is extented to the case of a partition for which the behavior is only controlled by the (total) mass (law). The sound reduction index derived by the means of the present step is referred to as **R stat.**

- ***Remarks in relation with the angular integration:***

  see corresponding § at step [P]

- ***Remarks in relation with the displayed results:***

  see corresponding § at step [P]

Step [R]

This steps aims at calculating the **sound reduction index with connections without sound leaks**

- ***Bibliography (references) :***

[R1] -	
[R2] -	
[R3]	
[R4] - -	
[R5] -	
[R6] -	

Comments :

Connections (for a double shell partition consisting of thin plates of set 0 and 2) are taken into account according various models:

- a general model (concerning the computation) for Rdif as shown in the tables below:

model	FAH	DAV	SHA1	SHA2	SHA3
source	[R1]	[R1]	[R1][R2]	[R1] [R2]	[R1]
number of identical plates for each leaf	1	1	according input data	according input data	1

- for the general model DAV only, a sub model for Rdif as shown in the tables below:

model	1990	2009	2012
source	[R4]	[R5]	[R6]

- for the general model DAV only, a sub model for Rdif as shown in the tables below:

model	BYO	PWL	ZER
source	-	[R6]	-
comment	Bring Your Own	Plasterboard Walls Leaves	ZERo

- for the general models SHA1, SHA2, SHA3 only, a model for connections as shown in the tables below:

model	L-L	L-P	P-P
source	[R1][R1]	[R1]	[R1][R2]
comment	Line-Line	Line-Point	Point-Point

Note: for the present revision of the software vibration transmission factor input data are not used for the computation (to be continued: work on progress)

- ***Remarks in relation with the angular integration:***

  in case of use of the model INT for plates of set 0 (general models SHA1 and SHA 2): see corresponding § at step [P]

- ***Remarks in relation with the displayed results:***

  see corresponding § at step [P]

  To be continued

Step [S]

This steps aims at calculating the **sound reduction index of sound leaks**

- ***Bibliography (references) :***

[S1]	
[S2] -	

- ***Comments :***

  In order to include the calculations in the general layout of the program, the following bibliographic source have not been used:

[S3] -	

(slit-shaped) leaks are taken into account according various models as shown in the tables below:

model	**GOM**	UNI
source	[S1][S2]	(*)

*the transmission factor is considered equal to unity

To be continued

Step [S']

This steps aims at calculating the **sound reduction index of sound leaks for 1 leaf** i.e. when is considered: not sets 0 to imax (as it is considered for step [S]) but 1 plate alone such as those of set 0, regardless of the selected quantity of such plates for set 0, regardless of the selected quantities of other elements, and with atmosphere at the front and at the rear regardless of the corresponding input data

- ***Bibliography (references) :***

  see corresponding § of step [S]

- ***Comments :***

  see corresponding § of step [S] To be continued

Step [T]

This steps aims at calculating the **sound reduction index for coupling 0 % with sound leaks**

- ***Bibliography (references) :***

[T1]	

- ***Comments :***

  The sound reduction index derived by the means of the present step is referenced **R stat**.

- ***Remarks in relation with the angular integration:***

  in case of use of the model INT: see corresponding § of step [P]

- ***Remarks in relation with the displayed results:***

  see corresponding § of step [P]

  To be continued

Step [T']

This steps aims at calculating the **sound reduction index with sound leaks for 1 leaf** i.e. when is considered: not sets 0 to imax (as it is considered for step [T]) but 1 plate alone such as those of set 0, regardless of the selected quantity of such plates for set 0, regardless of the selected quantities of other elements, and with atmosphere at the front and at the rear regardless of the corresponding input data

- ***Bibliography (references) :***

  see corresponding § of step [T]

- ***Comments :***

  see corresponding § of step [T]

  To be continued

Step [U]

This steps aims at calculating the **insertion loss for coupling 0 % with sound leaks**

- ***Comments :***

  The insertion loss derived by the means of the present step is referred to as **IL stat.**
  IL stat is not the insertion loss of the (total) acoustic structure. **IL stat** = **R stat** – **R' stat** where **R'stat** is the sound reduction index of 1 plate alone such as those of set 0, regardless of the selected quantity of such plates for set 0, regardless of the selected quantities of other elements, and with atmosphere at the front and at the rear regardless of the selected input data

  To be continued

Step [V]

This steps aims at calculating the **sound reduction index for coupling 100 % with sound leaks**

- ***Bibliography (references) :***

  See corresponding § of step [T]

- ***Comments :***

  The sound reduction index derived by the means of the present step is referred to as **R stat.**

- ***Remarks in relation with the angular integration:***

  in case of use of the model INT: see corresponding § of step [P]

- ***Remarks in relation with the displayed results:***

  see corresponding § of step [P]

  To be continued

Step [W]

This steps aims at calculating the **sound reduction index with connections with sound leaks (2 leaves)**

- ***Bibliography (references) :***

  See corresponding § of step [T]

- ***Comments :***

  The sound reduction index derived by the means of the present step is referred to as **R stat.**

- ***Remarks in relation with the angular integration:***

  in case of use of the model INT: see corresponding § at step [P]

- ***Remarks in relation with the displayed results:***

  see corresponding § at step [P] To be continued

2.3: How to use SILDIS

Operating conditions / security level / safety

See corresponding § in the chapter **General considerations**

For safety reasons, some cells of the original file provided to the user (as mentioned in the table below) for witch input data are foreseen to be entered by the user are pre-filled with the value “1/0”, among the yellow cells for which the color orange is used (*).

Worksheet	Cells
[in COALA]	E13, J37, W39
[in-out CODAP]	W23
[in-out COPPA]	X53, X54

* something like that

Worksheets

Regarding the COomputation of Plane Partitions, the software SILDIS is configurated in order to allow the user to access to 4 worksheets being linked as shown in fig.2.11 (the overview of the worksheets being shown in table below).

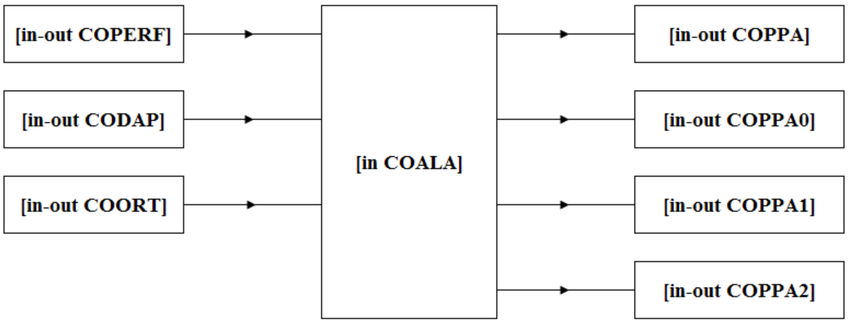


Fig. 2.11

Note concerning the worksheet [in COALA]: a rear atmosphere or an impervious rigid back are displayed, to be selected by the user depending on the conditions of the application for which the simulation is performed

Worksheet	Suitable for mountings	Input data	Results
[in-out COPERF]	perforated plates	for base plate	some of the parameters of the equivalent plate
[in-out CODAP]	damped plates	for layers of the composite	some of the parameters of the equivalent plate
[in-out COORT]	orthotropic plates	for the base plate and the geometry	some of the parameters of the equivalent plate
[in COALA]	all	for elements of sets, for reference spectrum	--
[in-out COPPA]	all (i.e. for the total acoustic structure as selected, with an impervious rigid back or with an atmospheric back as selected)	for limits of integration, for dimensions	sound absorption and sound transmission indicators
[in-out COPPA0]	with 0 leaf (without leaf), with an impervious rigid back	no input data (for the time being)	sound absorption and sound transmission indicators
[in-out COPPA1]	with 1leaf, with an atmospheric back *)	for specific complementary models	sound transmission indicators
[in-out COPPA2]	with 2 leaves, with an atmospheric back	for specific complementary models, for connections	sound transmission indicators

***** regardless of corresponding input data

Input data, alerts and results: the key points

The best use of the software requires the knowledge of some key points in relation with:

- the **input data** : see corresponding § in Section 1

  As far as thin plates are concerned, specific data bases (libraries) (will) allow the design to be made with in-built engineering data (constants) referred to as "Usual" in the worksheets of the software. Warning: some properties of the presently referenced materials still not have been checked by reliable sources. See also report [PhRxx-015x] Collection of soundproofing constructions systems: a companion to "User's manual for the software SILDIS"

- **data base (library) for thin plates (available in worksheet in COALA)**

  ✓ contents of the library: **21 possible references of material layers**
  ✓ among those references: 2-PLY and 3-PLY (reported from worksheet CODAP) and ORTHO (reported from worksheet COORT)

- **data base (library) for layers constituting the damped plates (available in worksheet in CODAP)**

  ✓ contents of the library: **21 possible references of material layers**

- **data base (library) for the base plate used for defining orthotropic plates (available in worksheet in COORT)**

  ✓ contents of the library: **21 possible references of material layers**

- some **alerts** in case of input data involving a warning of the user
- the place where (and the way) some **results** are presented

Those key points are reviewed worksheet per worksheet hereafter: the cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out COPERF]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Date	B3	Modification of the displayed date possible	
Project	D3	Input a name for the considered project	
Configuration	L3	Input a name for the considered configuration	
Comments	T3	Input a comment	
Reference	U16	Select a reference of material (in the proposed list) for each layer of interest	
Open area ratio	U22	Input a real positive number	

- ***Comments :***

Item	Cell for input	Foreseen action	Comment
Temperature	D5	--	Value reported from worksheet [in COALA] cell D6
Pressure	D6	--	Value reported from worksheet [in COALA] cell D7

- ***Main displays of the results for the perforated plate (table of results):***

Tables of results for the reference PERFO:

- **Young's modulus of the composite**: see cell U28
- **density of the composite**: see cell U29
- **Poisson's ratio of the composite**: see cell U30
- **loss factor of the composite**: see cell U31

Worksheet [in-out CODAP]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Date	B3	Modification of the displayed date possible	
Project	D3	Input a name for the considered project	
Configuration	L3	Input a name for the considered configuration	
Comments	T3	Input a comment	
Reference	V17 to W17; U48 to W48	Select a reference of material (in the proposed list) for each layer of interest	
Thickness	V23 to W23; U54 to W54	Input a real positive number	
Model of composite	L31;L41	Select a model (in the proposed list)	

- ***Comments :***

Item	Cell for input	Foreseen action	Comment
Temperature	D5	--	Value reported from worksheet [in COALA] cell D6
Pressure	D6	--	Value reported from worksheet [in COALA] cell D7

- ***Main displays of the results for the composite (table of results):***

Tables of results for the reference 2-PLY:

- **Young's modulus of the composite**: see cell V29
- **density of the composite**: see cell V30
- **Poisson's ratio of the composite**: see cell V31
- **loss factor of the composite**: see cell V32
- **thickness (overall) of the composite**: see cell V34

Tables of results for the reference 3-PLY:

- **Young's modulus of the composite**: see cell V39 (*)
- **density of the composite**: see cell V40
- **Poisson's ratio of the composite**: see cell V41
- **loss factor of the composite**: see cell V42 (*)
- **thickness (overall) of the composite**: see cell V44

*limit at low frequency is displayed for the composite **reference 3-PLY**

Worksheet [in-out COORT]

- ***Input data :***

<table>
<tr><th>Item</th><th>Cell for input</th><th>Foreseen action</th><th colspan="2">Comment</th></tr>
<tr><td>Date</td><td>B3</td><td>Modification of the displayed date possible</td><td colspan="2"></td></tr>
<tr><td>Project</td><td>D3</td><td>Input a name for the considered project</td><td colspan="2"></td></tr>
<tr><td>Configuration</td><td>M3</td><td>Input a name for the considered configuration</td><td colspan="2"></td></tr>
<tr><td>Comments</td><td>U3</td><td>Input a comment</td><td colspan="2"></td></tr>
<tr><td>To get fc* (Hz)</td><td>M8</td><td>Input a real positive number</td><td rowspan="2">no compulsory input data</td><td>If a particular value of fc* is wished</td></tr>
<tr><td>To get fc*.h =</td><td>P8</td><td>Input a real positive number</td><td>If a particular value of fc*.h is wished</td></tr>
<tr><td>Reference of base plate</td><td>L9</td><td>Select a reference of layer (in the proposed list) for each layer of interest</td><td colspan="2"></td></tr>
<tr><td>Thickness</td><td>J15</td><td>Input a real positive number</td><td colspan="2">The thickness of the plate used before profiling is considered (not the overall thickness after profiling)</td></tr>
<tr><td>Model of orthotropic plate</td><td>J17</td><td>Select a model (in the proposed list)</td><td colspan="2"></td></tr>
<tr><td>hw</td><td>J23</td><td>Input a real positive number</td><td colspan="2"></td></tr>
<tr><td>l</td><td>J24</td><td>Input a real positive number</td><td colspan="2"></td></tr>
<tr><td>r</td><td>J25</td><td>Input a real positive number</td><td colspan="2">for model RIB only</td></tr>
<tr><td>T</td><td>J26</td><td>Input a real positive number</td><td colspan="2">for model CLA only</td></tr>
<tr><td>Surface density</td><td>L28</td><td>Input a real positive number</td><td colspan="2" rowspan="2">for model MOI only</td></tr>
<tr><td>Overall thickness</td><td>L29</td><td>Input a real positive number</td></tr>
<tr><td>To get fcz* (Hz)</td><td>M30</td><td>Input a real positive number</td><td rowspan="5">for model MOI only (no compulsory input data)</td><td>If a particular value of fc* is wished</td></tr>
<tr><td>To get M’’’.fcz* (kg.Hz) =</td><td>N30</td><td>Input a real positive number</td><td>If a particular value of M’’’.fcz* is wished</td></tr>
<tr><td>To get M’’’.2π.fcz*/Z_0* =</td><td>O30</td><td>Input a real positive number</td><td>If a particular value of M’’’.2.πi.fcz*/Z_0* is wished</td></tr>
<tr><td>To get fcz*.d’’’ =</td><td>P30</td><td>Input a real positive number</td><td>If a particular value of fcz*.d’’’ is wished</td></tr>
<tr><td>To get Zm=M’’’.fcz*/Z_0 =</td><td>Q30</td><td>Input a real positive number</td><td>If a particular value of Zm=M’’’.fcz*/Z_0 is wished</td></tr>
<tr><td>Bending stiffness (per unit width) in the x-direction (maximum) D’x = D’zz = D_{11}</td><td>L31</td><td>Input a real positive number</td><td rowspan="2">for model MOI only</td><td></td></tr>
<tr><td>Bending stiffness (per unit width) in the z-direction (minimum) D’z = D’xx = D_{22}</td><td>L32</td><td>Input a real positive number</td><td>If a particular value of fcz* (resp. M’’’.fcz*, M’’’.2.π.fcz*/Z_0, fcz*.d’’’, Zm=M’’’.fcz*/Z_0 is wished input the value given in M32 (resp. N32, O32, P32, Q32)</td></tr>
<tr><td>Torsional rigidity (per unit width) D_{12} +2D_{66}</td><td>L35</td><td>Input a real positive number</td><td colspan="2">for model MOI only</td></tr>
<tr><td>Model of bending stiffness: maximum</td><td>J50</td><td>Select a model (in the proposed list)</td><td colspan="2">for model CLA only</td></tr>
<tr><td>Model of bending stiffness: minimum</td><td>J51</td><td>Select a model (in the proposed list)</td><td colspan="2">for model CLA only</td></tr>
</table>

- ***Comments :***

Item	Cell for input	Foreseen action	Comment
Temperature	D5	--	Value reported from worksheet [in COALA] cell D6
Pressure	D6	--	Value reported from worksheet [in COALA] cell D7

- ***Main displays of the results for the equivalent plate (not for the model MOI):***

  - **surface density of the equivalent plate**: see cell J28
  - **overall thickness of the equivalent plate**: see cell J29
  - **bending stiffness (per unit width) in the x-direction (maximum):** see cell J31
  - **bending stiffness (per unit width) in the z-direction (minimum):** see cell J32
  - **torsional rigidity (per unit width):** see cell J35

Worksheet [in COALA]

See corresponding § in Section 1

Worksheet [in-out COPPA]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Limitation of radiation ? (0/1)	E8	For NO input 0, for YES input 1	
Large power used for the calculation	E9	Input a positive real	
Size of the baffle in which the partition is symmetrically mounted along the x-direction	X49	Input a positive real	
Size of the baffle in which the partition is symmetrically mounted along the z-direction	X50	Input a positive real	
Size of the partition along the x-direction	X53	Input a positive real	
Size of the partition along the z-direction	X54	Input a positive real	
Model for the calculation of f11	X56	Select a model (in the proposed list)	
Fi min (°)	I71	Select a value (in the proposed list)	
Fi max (°)	K71	Select a value (in the proposed list)	
Teta min (°)	P71	Select a value (in the proposed list)	
Teta max (°)	R71	Select a value (in the proposed list)	
Model for teta L	U71	Select a model (in the proposed list)	
alpha sab max	AF94	Input a positive real	
length of slit (m)	E97	Input a positive real	
width of slit (m)	H97	Input a positive real	
model	K97	Select a model (in the proposed list)	

- ***Main displays of the results :***

  Tables of results:

  - **lowest critical frequency of the thin plates**: see line 41 (columns T to Y)(not displayed for the reference 3-PLY because depending on frequency)

  - **highest critical frequency of the thin plates**: see line 42 (columns T to Y)(not displayed for the reference 3-PLY because depending on frequency)

<u>**Tables of results and graphs for the partition**</u>

- **absorption coefficient for normal incidence**: see lines 73 to 91 (columns A to L)

<u>**Tables of results and graphs for the partition, with an integration within selected limits for orientation & incidence**</u>

- **absorption coefficient for a statistic incidence**: see lines 73to 94 (columns M to Z)
- **Sabine's factor**: see lines 73 to 94 (columns AA to AN)

<u>**Tables of results and graphs for the partition (except for insertion loss: see below), with an integration within selected limits for orientation & incidence, with sound leaks**</u>

- **sound reduction index (coupling 0 %)**: see lines 99 to 121 (columns A to L)
- **insertion loss (coupling 0 %)**: see lines 99 to 118 (columns M to Z)

  Nota: the considered insertion loss is not the insertion loss of the partition i.e. the (total) acoustic structure. The insertion loss IL stat is defined as IL stat = R stat – R' stat with R' stat: sound reduction index of 1 plate such as those of set 0 whatever the quantity of such plates selected for set 0 is (angular integration & sound leaks included)

- **acoustic power without (resp. with) the partition (coupling 0 %)**: see lines 99 to 117 (columns AA to AJ)

Worksheet [in-out COPPA0]

- ***<u>Input data</u> :*** ***n***o input data required
- ***<u>Main displays of the results :</u>***

<u>**Tables of results and graphs for sets 1 to imax, without thin plate(s), with an impervious rigid back**</u>

- **surface impedance at normal incidence**: see lines 47 to 65 (columns A to L for real part, columns M to X for imaginary part)
- **normalized surface impedance at normal incidence**: see lines 67 to 85 (columns A to L for real part, columns M to X for imaginary part)
- **absorption coefficient for normal incidence**: see lines 87 to 105 (columns A to L)

Worksheet [in-out COPPA1]

- ***<u>Input data :</u>***

Item	Cell for input	Foreseen action	Comment
boundary conditions	E77	Select a model (in the proposed list)	
model of radiation ratio (of free bending waves)	K77	Select a model (in the proposed list)	
Simplified transmission factor for normal incidence (0/1)	G81	For NO input 0, for YES input 1	
General model (for R)	K81	Select a model (in the proposed list)	
model of forced transmission	E85	Select a model (in the proposed list)	
model of resonant transmission	E90, K90	Select a model (in the proposed list)	
model of transmission	E95, K95	Select a model (in the proposed list)	
frequency range where f ≈ fc	E99, K99	Select a number of 1/3 octave bands	

- ***Comments :***

Item	Cell	Foreseen action	Comment
STOP 3-PLY	L81, L82	--	In case of such an alert, the accuracy of the program with all the models has not been checked
not exact for f < fc	C86, D86	--	In case of such an alert, the user has to be prepared to get approximate results below the frequency displayed due to imperfections of the chosen model
STOP: valid model NI1	B87	--	In case of such an alert, the model has to be changed for the same model as in cell E90
STOP: valid model NI2	D87	--	In case of such an alert, the model has to be changed for the same model as in cell E90
STOP: radiation ratio not valid	D91	--	In case of such an alert, the input data of cell K77 has to be changed
STOP: radiation ratio not valid	J91	--	In case of such an alert, the input data of cell K77 has to be changed
STOP: valid model NI1	B92	--	In case of such an alert, the model has to be changed for the same model as in cell E85
STOP: valid model NI2	D92	--	In case of such an alert, the model has to be changed for the same model as in cell E85
STOP: radiation ratio not valid	J96	--	In case of such an alert, the input data of cell K77 has to be changed

- ***Main displays of the results :***

Tables of results and graphs for 1 plate such as those of set 0 alone (whatever the quantity of such plates selected for set 0 is):

- **radiation ratio (of free bending waves)**: see lines 75 to 99 (columns M to Z)
- **sound reduction index**: see lines 75 to 103 (columns AA to AN)

Worksheet [in-out COPPA2]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
general model (for Rdif)	K76	Select a model (in the proposed list)	
sub-model (for general model DAV)	K80	Select a model (in the proposed list)	
model for connections (for general models SHA1,SHA2,SHA3)	K82	Select a model (in the proposed list)	
distance between line-type connections (m)	K85	Input a positive real	
vibration transmission factor (not for general models FAH,DAV,SHA1,SHA2,SHA3)	K86	Input a positive real	
compliance of connections for the general model DAV, for the compliance model BYO (in mN-1)	K87	Input a positive real	
model of compliance (for general model DAV)	K89	Select a model (in the proposed list)	
number of connections per m2 (m-2)	K92	Input a positive real	
vibration transmission factor (not for general models FAH,DAV,SHA1,SHA2,SHA3)	K93	Input a positive real	
compliance of connections for the general model DAV, for the compliance model BYO (in mN-1)	K94	Input a positive real	

- ***Comments :***

  no comment

- ***Main displays of the results :***

  Tables of results and graphs of a double-leaf partition with connections between thin plates of sets 0 and 2 (for imax= 2):

  - **sound reduction index**: see lines 74 to 98 (columns AA to AN)

2.4: Examples of computation with SILDIS

Example 2.4.0 porous medium with series cloth

Envisaged application

It is wished to compute the absorption coefficient of the lining considered in the corresponding § in Section 1 (with an impervious rigid back) for a normal incidence.

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA] for example 2.4.0 only See corresponding § in Section 1

Worksheet [in-out COPERF] for example 2.4.0 No input data required for the example of computation

Worksheet [in-out CODAP] for example 2.4.0 and for example 2.4.1

Item	Cell for input	Foreseen action	Input	See placemark / comment
Thickness	W23	Input a real positive number	0.001 (*)	-

*see § **2. 3: How to use SILDIS Operating conditions / security level / safety**

Worksheet [in-out COORT] for example 2.4.0 No input data required for the example of computation

Worksheet [in-out COPPA] for example 2.4.0 No input data required for the example of computation

Worksheet [in-out COPPA0] for example 2.4.0 No input data required for the example of computation

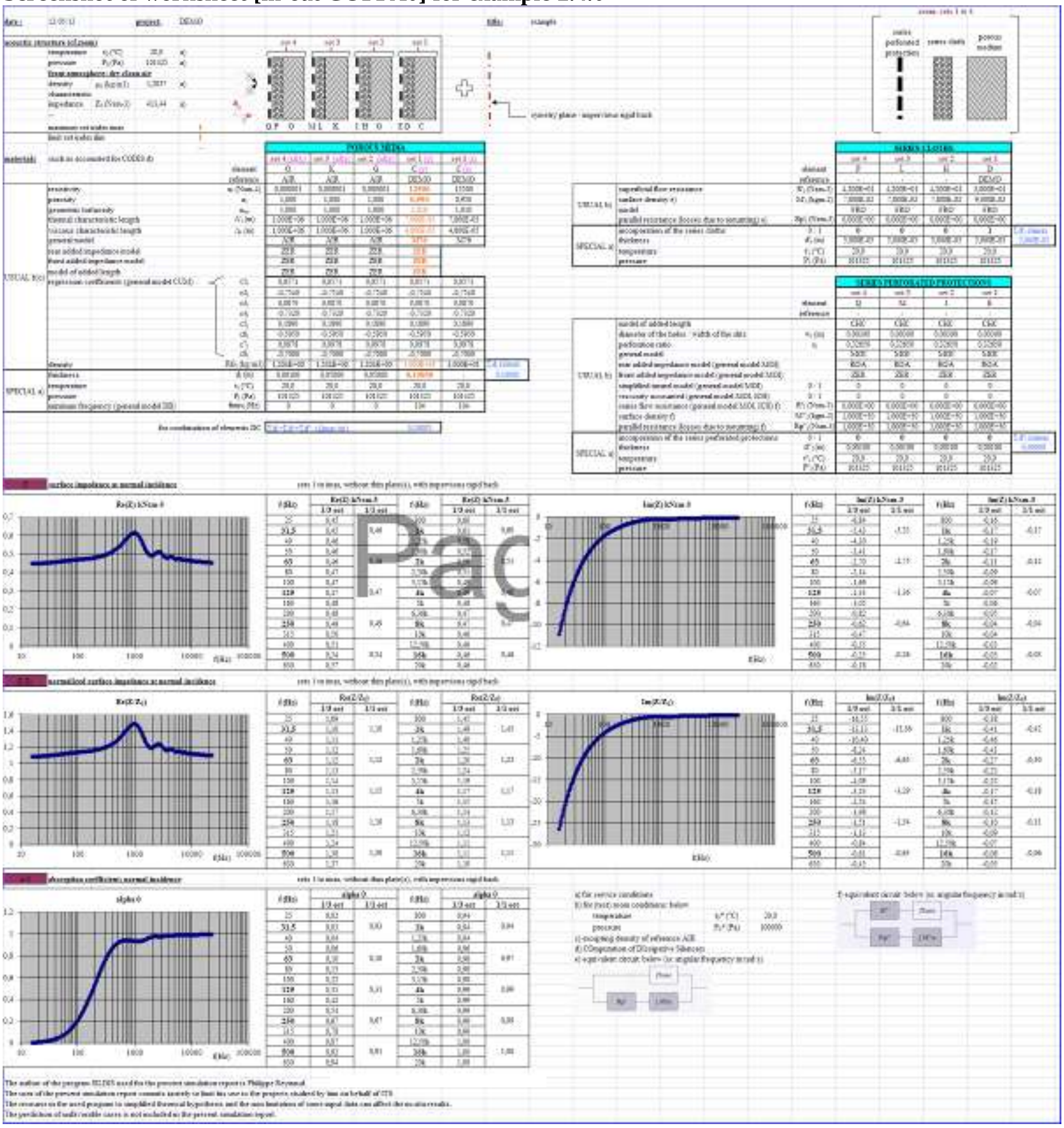
Worksheet [in-out COPPA1] for example 2.4.0 No input data required for the example of computation

Worksheet [in-out COPPA2] for example 2.4.0 No input data required for the example of computation

Screenshots of the worksheets (for the example of computation)

Screenshot of worksheet [in COALA] for example 2.4.0 only See corresponding § in Section 1

Screenshot of worksheet [in-out COPPA0] for example 2.4.0



Example 2.4.1a single isotropic plate (general method)

Envisaged application

It is foreseen to use the following conditions: temperature 20 °C [15], pressure 101325 Pa [16].
The reference spectrum is supposed of the type "pink noise" [19] with a sound power level of 130 dB/oct [20]

It is wished to compute the sound reduction index (with an atmospheric back) [24] of 1 [25] aluminium plate [26] of thickness 2mm [27], the (intrinsic) losses of the material being considered [28] with a infinite extend [29] and by an integration of the transmission factor between 0 and 90° [30]. No sound leak is considered [31].

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA] for example 2.4.1a

Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark / comment
Temperature	D6	Input a real number	20	[15]
Pressure	D7	Input a real positive number	101325	[16]
Rear atmosphere ? (0/1)	O8	For NO input 0, for YES input 1	1	[24]
Maximum set index **imax**	E13	Input an integer from 1 to 4	1	[25]
Reference	J18 to K18	Select a reference (material in the proposed list) for each layer of interest	AIR	-
Incorporation of the series perforated protections (0/1)	J57	For NO press 0, for YES press 1	0	-
Incorporation of the series cloths (0/1)	W23	For NO input 0, for YES input 1	0	-
Reference	W31	Select a reference (in the proposed list)	ALU	[26]
Model of losses	W36	Select a model (in the proposed list)	INT	[28]
Model of effective critical frequency	W37	Select a model (in the proposed list)		
Number of identical plates	W38	Input a real positive number	1	[25]
Thickness	W39	Input a real positive number	0.002	[27]
Lw0 only known per 1/1 octave frequency band (0/1)	R62	For NO input 0, for YES input 1	1	[20]
Lw0	B65 to K65	Input a real positive number as requested for a 1/1 octave band sound power level	130	[20]

Worksheet [in-out COPERF] for example 2.4.1a No input data required for the example of computation

Worksheet [in-out CODAP] for example 2.4.1a See corresponding § for **example 2.4.0**

Worksheet [in-out COORT] for example 2.4.1a No input data required for the example of computation

Worksheet [in-out COPPA] for example 2.4.1a

Item	Cell for input	Foreseen action	Input	See placemark / comment
Size of the baffle in which the partition is symmetrically mounted along the x-direction	X49	Input a positive real	4.5	**(*)**
Size of the baffle in which the partition is symmetrically mounted along the z-direction	X50	Input a positive real	3.5	**(*)**
Size of the partition along the x-direction	X53	Input a positive real	1	**(*)**
Size of the partition along the z-direction	X54	Input a positive real	1	**(*)**
Fi min (°)	I71	Select a value (in the proposed list)	5.625	-
Fi max (°)	K71	Select a value (in the proposed list)	84.375	-
Teta min (°)	P71	Select a value (in the proposed list)	0	[30]
Teta max (°)	R71	Select a value (in the proposed list)	89.375	[30]
Model for teta L	U71	Select a model (in the proposed list)	90°	[29]
length of slit (m)	E97	Input a positive real	1E-50	[31]
width of slit (m)	H97	Input a positive real	1E-50	[31]
model	K97	Select a model (in the proposed list)	-	[31]

*see § **2. 3: How to use SILDIS <u>Operating conditions / security level / safety</u>**

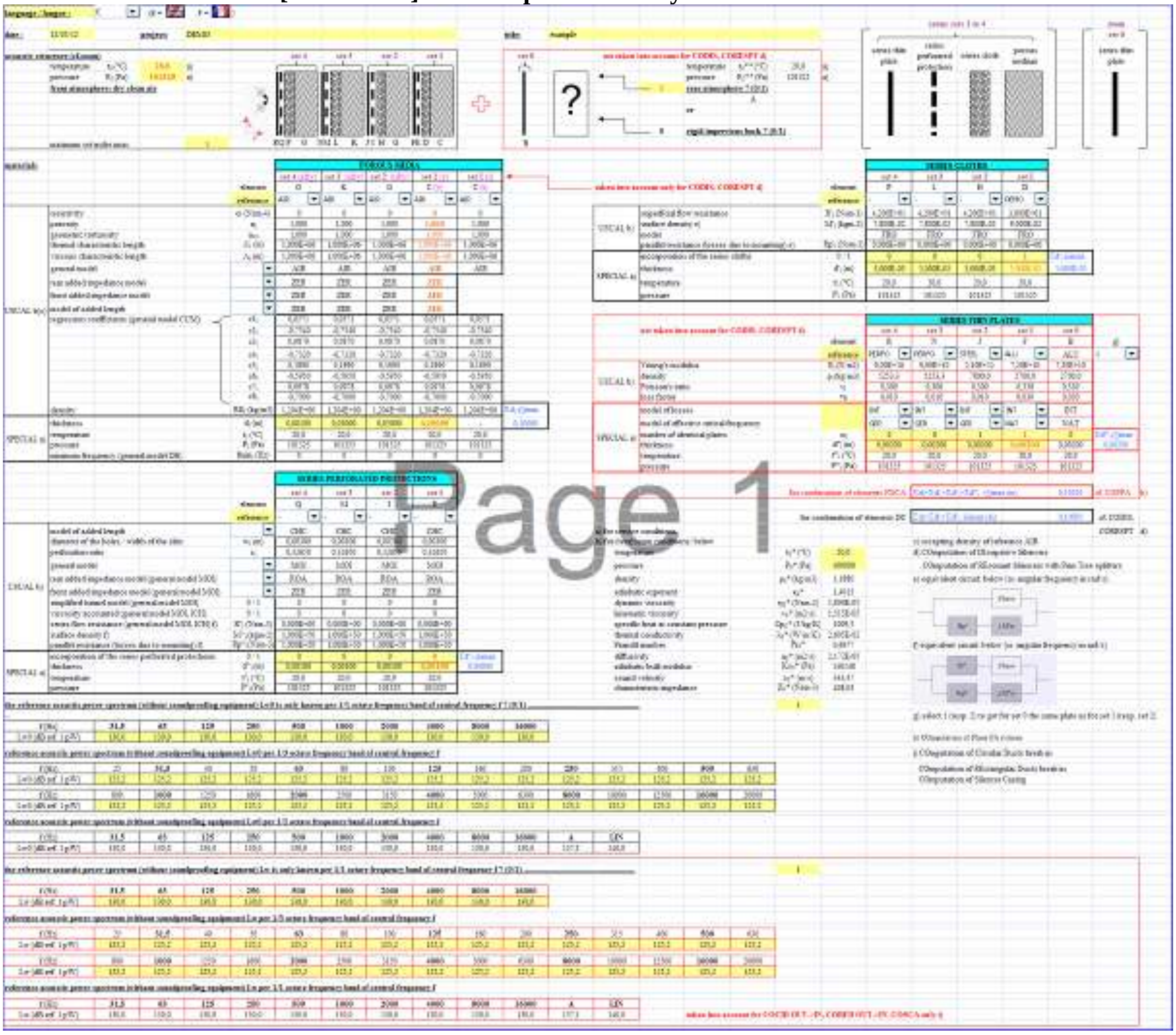
Worksheet [in-out COPPA0] for example 2.4.1a No input data required for the example of computation

Worksheet [in-out COPPA1] for example 2.4.1a No input data required for the example of computation

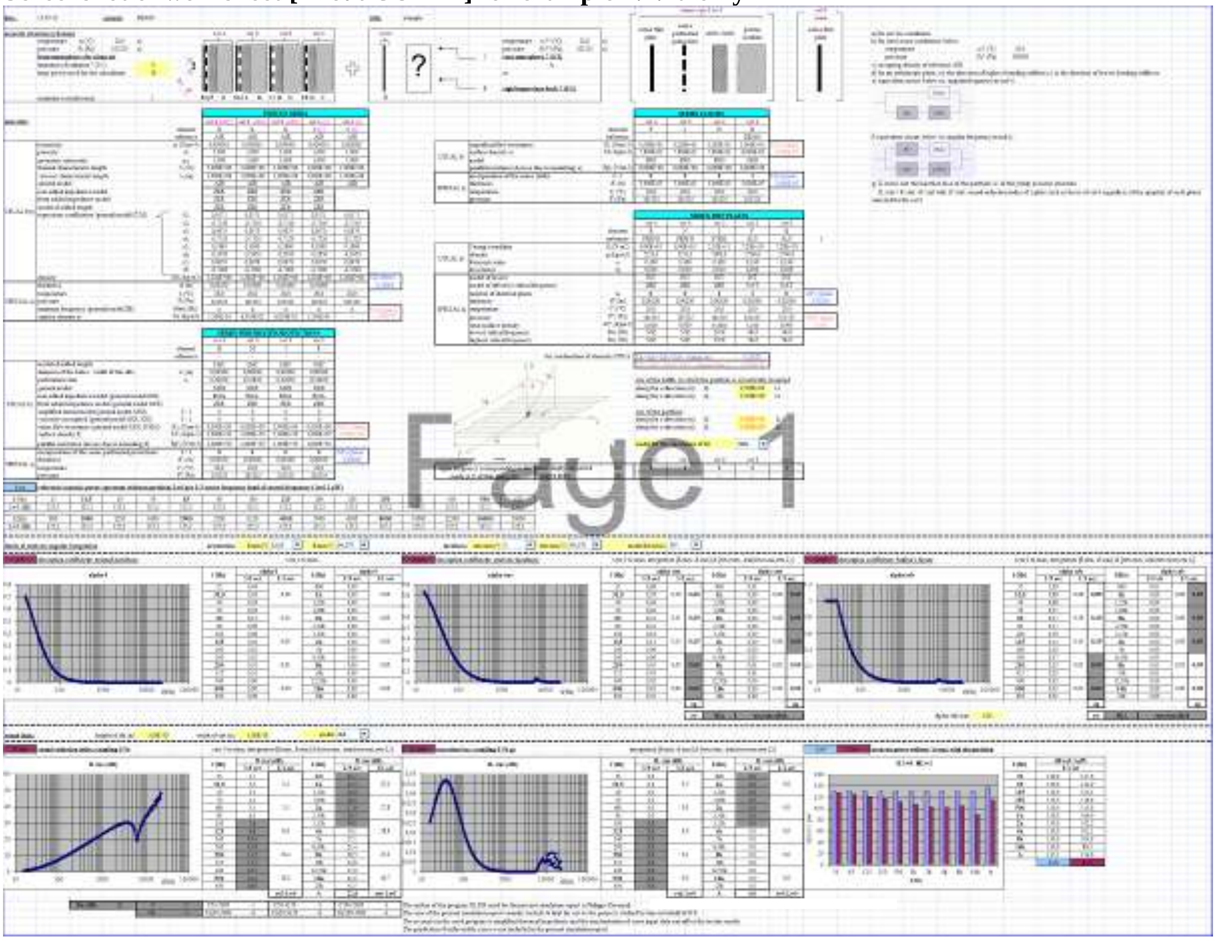
Worksheet [in-out COPPA2] for example 2.4.1a No input data required for the example of computation

Screenshots of the worksheets (for the example of computation)

Screenshot of worksheet [in COALA] for example 2.4.1a only



Screenshot of worksheet [in-out COPPA] for example 2.4.1a only



Example 2.4.1b single isotropic plate (alternative method)

Envisaged application

It is foreseen to use the following conditions: temperature 20 °C [15], pressure 101325 Pa [16].
The reference spectrum is supposed of the type "pink noise" [19] with a sound power level of 130 dB/oct [20]

It is wished to compute the sound reduction index (with an atmospheric back) [24] of 1 [25] aluminium plate [26] of thickness 2mm [27], the (intrinsic) losses of the material being considered [28] with a infinite extend [29] and by an integration of the transmission factor between 0 and 90° [30]. No sound leak is considered [31].

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA] for example 2.4.1b

Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark / comment
Temperature	D6	Input a real number	20	[15]
Pressure	D7	Input a real positive number	101325	[16]
Reference	W31	Select a reference (in the proposed list)	ALU	[26]
(1/2)	Y31	Select a number (in the proposed list)	select 1	-
Model of losses	W36	Select a model (in the proposed list)	INT	[28]
Model of effective critical frequency	W37	Select a model (in the proposed list)		
Number of identical plates	X38	Input a real positive number	1	[25]
Thickness	W39	Input a real positive number	0.002	[27]
Lw0 only known per 1/1 octave frequency band (0/1)	R62	For NO input 0, for YES input 1	1	[20]
Lw0	B65 to K65	Input a real positive number as requested for a 1/1 octave band sound power level	130	[20]

Worksheet [in-out COPERF] for example 2.4.1b No input data required for the example of computation

Worksheet [in-out CODAP] for example 2.4.1b See corresponding § for **example 2.4.0**

Worksheet [in-out COORT] for example 2.4.1b No input data required for the example of computation

Worksheet [in-out COPPA] for example 2.4.1b

Item	Cell for input	Foreseen action	Input	See placemark / comment
Size of the baffle in which the partition is symmetrically mounted along the x-direction	X49	Input a positive real	4.5	**(*)**
Size of the baffle in which the partition is symmetrically mounted along the z-direction	X50	Input a positive real	3.5	**(*)**
Size of the partition along the x-direction	X53	Input a positive real	1	**(*)**
Size of the partition along the z-direction	X54	Input a positive real	1	**(*)**
Model for the calculation of f11	X56	Select a model (in the proposed list)	-	-
Fi min (°)	I71	Select a value (in the proposed list)	5.625	-
Fi max (°)	K71	Select a value (in the proposed list)	84.375	-
Teta min (°)	P71	Select a value (in the proposed list)	0	[30]
Teta max (°)	R71	Select a value (in the proposed list)	89.375	[30]
Model for teta L	U71	Select a model (in the proposed list)	90°	[29]
length of slit (m)	E97	Input a positive real	1E-50	[31]
width of slit (m)	H97	Input a positive real	1E-50	[31]
model	K97	Select a model (in the proposed list)	-	[31]

Worksheet [in-out COPPA0] for example 2.4.1b No input data required for the example of computation

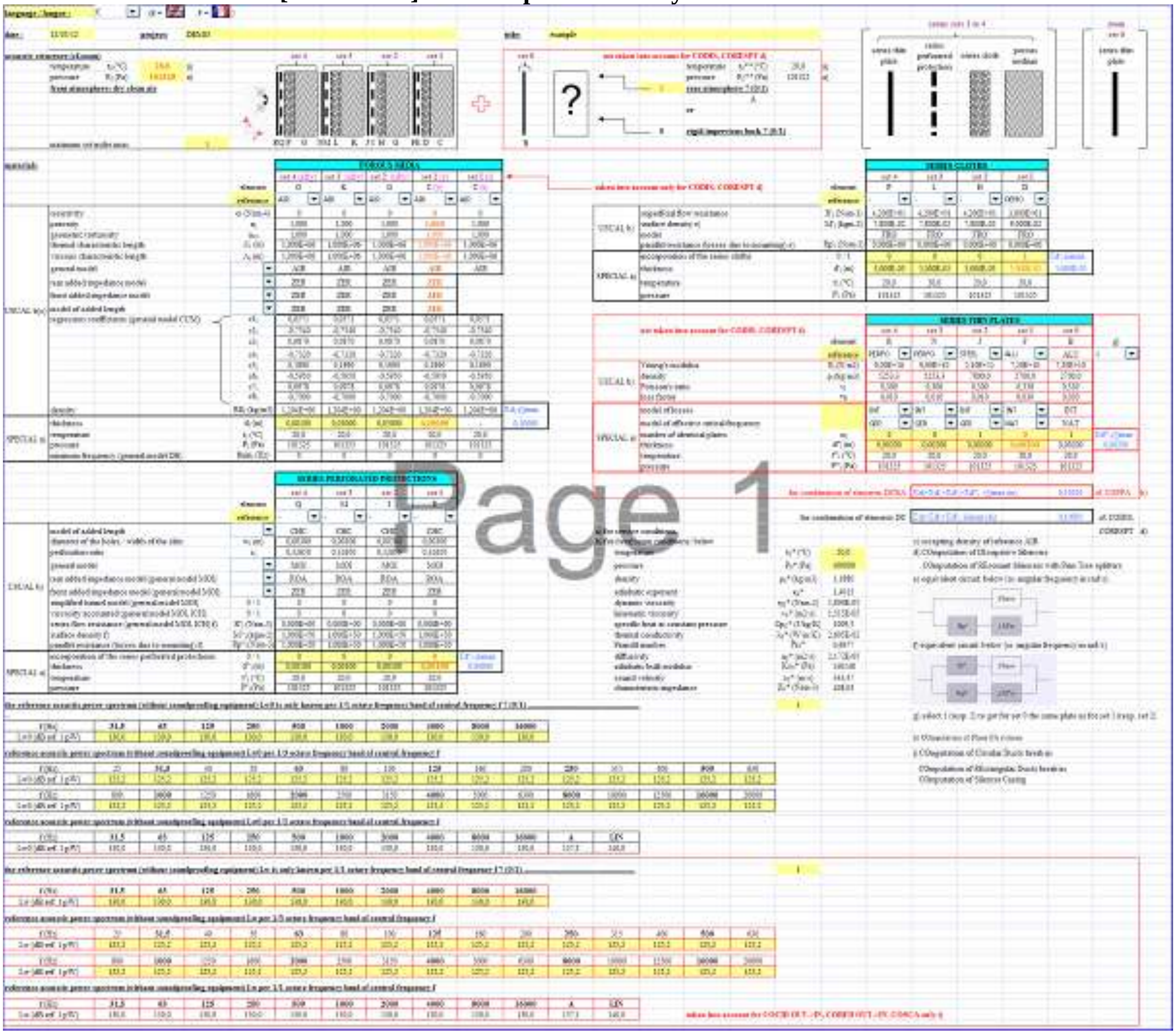
Worksheet [in-out COPPA1] for example 2.4.1b No input data required for the example of computation

Item	Cell for input	Foreseen action	Input	See placemark / comment
Simplified transmission factor for normal incidence (0/1)	G81	For NO input 0, for YES input 1	0	-
General model (for R)	K81	Select a model (in the proposed list)	MOI	[30]
model of forced transmission	E85	Select a model (in the proposed list)	INT	[30]
model of resonant transmission	E90, K90	Select a model (in the proposed list)	ZER, INT	[30]
model of transmission	E95, K95	Select a model (in the proposed list)	NAT, NAT	[30]
frequency range where f ≈ fc	E99, K99	Select a number of 1/3 octave bands	-, -	-

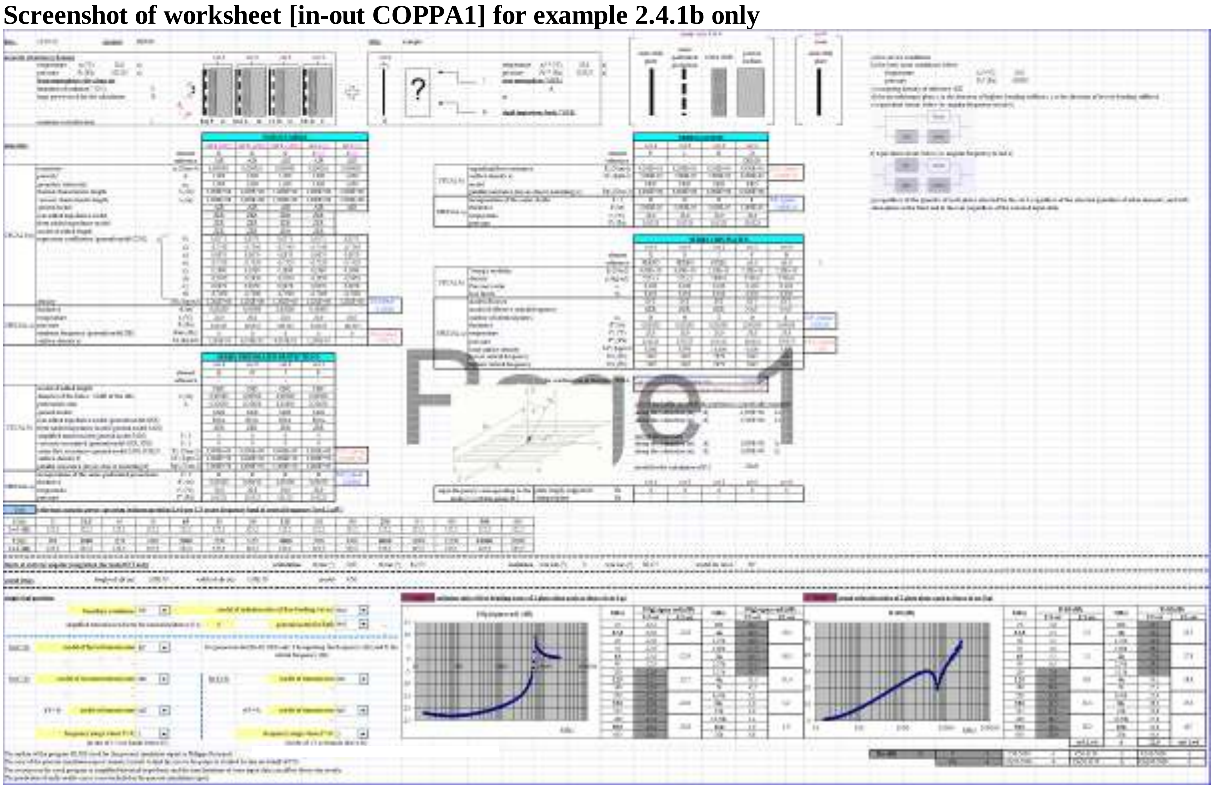
Worksheet [in-out COPPA2] for example 2.4.1b No input data required for the example of computation

Screenshots of the worksheets (for the example of computation)

Screenshot of worksheet [in COALA] for example 2.4.1b only



Screenshot of worksheet [in-out COPPA1] for example 2.4.1b only



Example 2.4.2 double leaf partition with connections

Envisaged application

It is foreseen to use the following conditions: temperature 20 °C [15], pressure 101325 Pa [16].
The reference spectrum is supposed of the type "pink noise" [19] with a sound power level of 130 dB/oct [20]

It is wished to compute the sound reduction index (with an atmospheric back) [24] of a double-leaf partition consisting of:

-1 [25] aluminium plate [26] of thickness 2mm [27], the (intrinsic) losses of the material being considered [28]
-1 [32] steel plate [33] of thickness 2mm [34], the (intrinsic) losses of the material being considered [35]

with a infinite extend [29] and by an integration of the transmission factor between 0 and 90° [30]. No sound leak is considered [31].

The interspace is assumed to be filled with the porous medium reference DEMO [36], with a thickness of 100mm [37]
The general model SHA3 is considered [38] for Line-Line connections [39] having a distance of 600mm [40]

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA] for example 2.4.2

Item	Cell for input	Foreseen action (see §1.3)	Input	See placemark / comment
Temperature	D6	Input a real number	20	[15]
Pressure	D7	Input a real positive number	101325	[16]
Rear atmosphere ? (0/1)	O8	For NO input 0, for YES input 1	1	[24]
Maximum set index **imax**	E13	Input an integer from 1 to 4	2	-
Reference	J18 to K18	Select a reference (material in the proposed list) for each layer of interest	DEMO	[36]
Thickness	I37,J37	Input a real positive number	0.05,0.05	[37]
Incorporation of the series perforated protections (0/1)	I57,J57	For NO press 0, for YES press 1	0	-
Incorporation of the series cloths (0/1)	V23,W23	For NO input 0, for YES input 1	0	-
Reference	V31,W31	Select a reference (in the proposed list)	STEEL,ALU	[33],[26]
(1/2)	Y31	Select a number (in the proposed list)	select 1	-
Model of losses	V36,W36	Select a model (in the proposed list)	INT,INT	[35],[28]
Model of effective critical frequency	V37,W37	Select a model (in the proposed list)		
Number of identical plates	V38,X38	Input a real positive number	1,1	[32],[25]
Thickness	V39,W39	Input a real positive number	0.002,0.002	[34], [27]
Lw0 only known per 1/1 octave frequency band (0/1)	R62	For NO input 0, for YES input 1	1	[20]
Lw0	B65 to K65	Input a real positive number as requested for a 1/1 octave band sound power level	130	[20]

Worksheet [in-out COPERF] for example 2.4.2 No input data required for the example of computation

Worksheet [in-out CODAP] for example 2.4.2 See corresponding § for **example 2.4.0**

Worksheet [in-out COORT] for example 2.4.2 No input data required for the example of computation

Worksheet [in-out COPPA] for example 2.4.2

Item	Cell for input	Foreseen action	Input	See placemark / comment
Size of the baffle in which the partition is symmetrically mounted along the x-direction	X49	Input a positive real	4.5	**(*)**
Size of the baffle in which the partition is symmetrically mounted along the z-direction	X50	Input a positive real	3.5	**(*)**
Size of the partition along the x-direction	X53	Input a positive real	1	**(*)**
Size of the partition along the z-direction	X54	Input a positive real	1	**(*)**
Model for the calculation of f11	X56	Select a model (in the proposed list)	-	-
Fi min (°)	I71	Select a value (in the proposed list)	5.625	-
Fi max (°)	K71	Select a value (in the proposed list)	84.375	-
Teta min (°)	P71	Select a value (in the proposed list)	0	[30]
Teta max (°)	R71	Select a value (in the proposed list)	89.375	[30]
Model for teta L	U71	Select a model (in the proposed list)	90°	[29]
length of slit (m)	E97	Input a positive real	1E-50	[31]
width of slit (m)	H97	Input a positive real	1E-50	[31]
model	K97	Select a model (in the proposed list)	-	[31]

Worksheet [in-out COPPA0] for example 2.4.2 No input data required for the example of computation

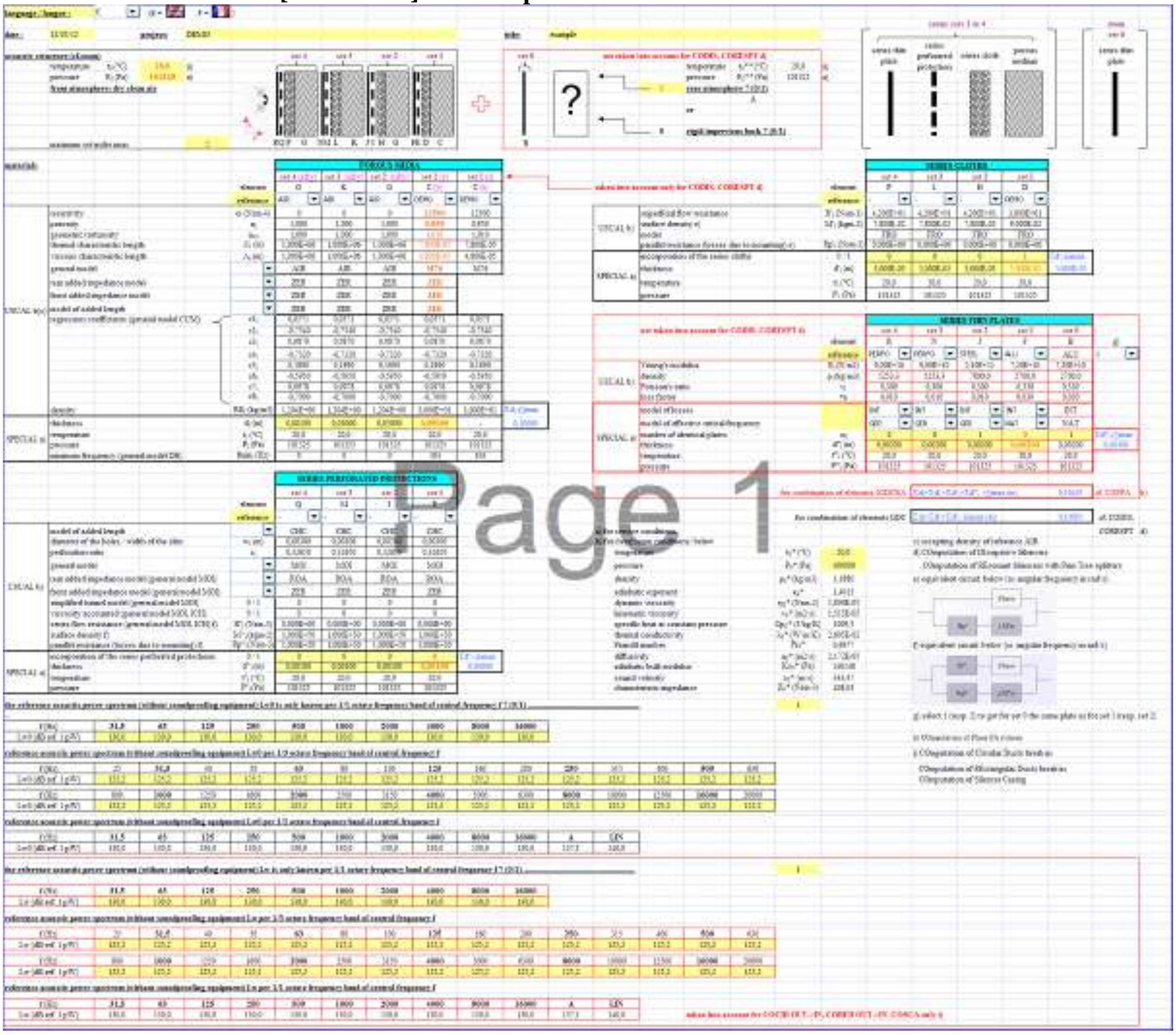
Worksheet [in-out COPPA1] for example 2.4.2 No input data required for the example of computation

Worksheet [in-out COPPA2] for example 2.4.2

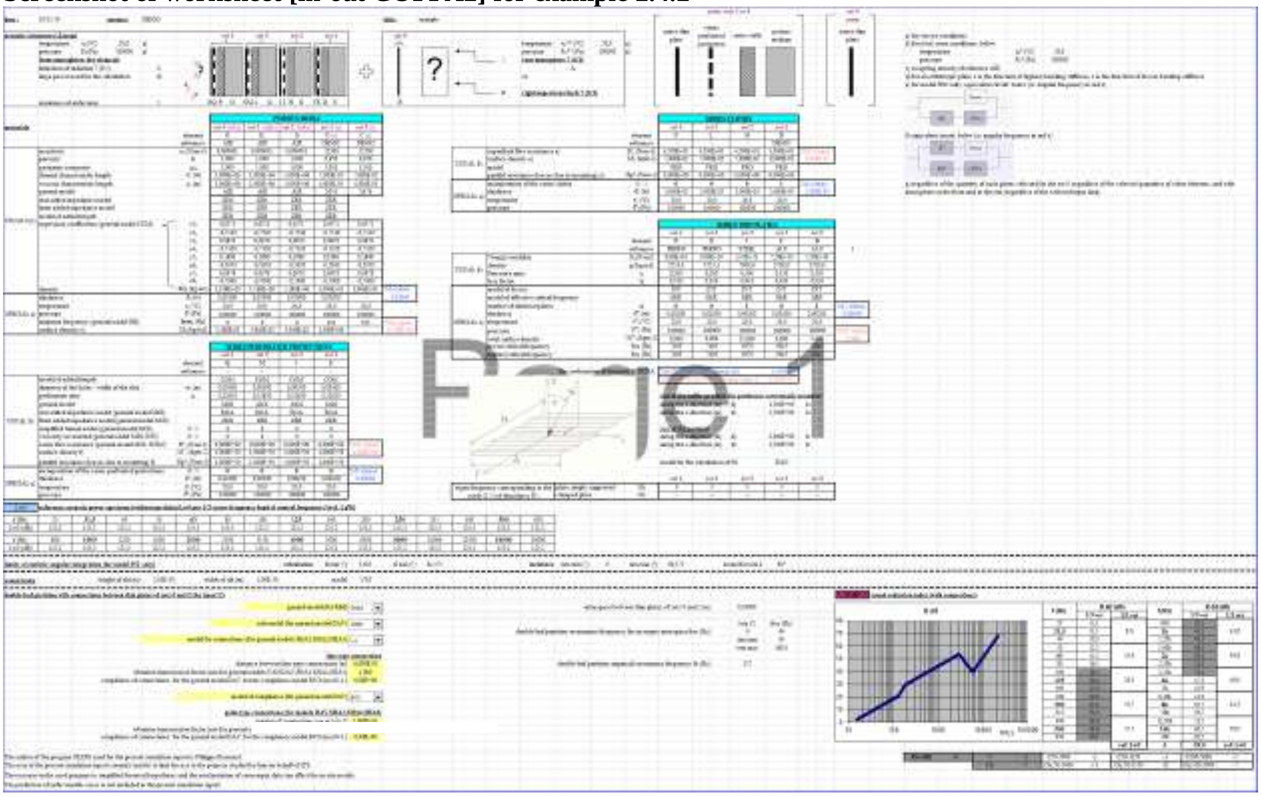
Item	Cell for input	Foreseen action	Input	See placemark / comment
general model (for Rdif)	K76	Select a model (in the proposed list)	SHA3	[38]
sub-model (for general model DAV)	K80	Select a model (in the proposed list)	-	
model for connections (for general models SHA1,SHA2,SHA3)	K82	Select a model (in the proposed list)	L-L	[39]
distance between line-type connections (m)	K85	Input a positive real	0.6	[40]
vibration transmission factor (not for general models FAH,DAV,SHA1,SHA2,SHA3)	K86	Input a positive real	-	-
compliance of connections for the general model DAV, for the compliance model BYO (in mN-1)	K87	Input a positive real	-	-
model of compliance (for general model DAV)	K89	Select a model (in the proposed list)	-	-
number of connections per m2 (m-2)	K92	Input a positive real	-	-
vibration transmission factor (not for general models FAH,DAV,SHA1,SHA2,SHA3)	K93	Input a positive real	-	-
compliance of connections for the general model DAV, for the compliance model BYO (in mN-1)	K94	Input a positive real	-	-

<u>Screenshots of the worksheets (for the example of computation)</u>

Screenshot of worksheet [in COALA] for example 2.4.2



Screenshot of worksheet [in-out COPPA2] for example 2.4.2



Example 2.4.3 perforated plate

Envisaged application

It is foreseen to compute the engineering constants for a perforated plate consisting of a steel plate [41] with an open area ratio of 32.65 % [42].

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out COPERF] for example 2.4.3

Item	Cell for input	Foreseen action	Input	See placemark / comment
Reference	U16	Select a reference of material (in the proposed list) for each layer of interest	STEEL	[41]
Open area ratio	U22	Input a real positive number	0.03265	[42]

Screenshots of the worksheets (for the example of computation)

Screenshot of worksheet [in-out COPERF] for example 2.4.3

Example 2.4.4 plate with an extensional damping

Envisaged application

It is foreseen to compute the engineering constants for a damped plate consisting of:

-1 aluminum plate [43] of thickness 2mm [44]
-1 viscoelastic plate (reference VSCO in the database) [45] of thickness 2mm [46]

The model of composite MOI is considered [47]

Input data

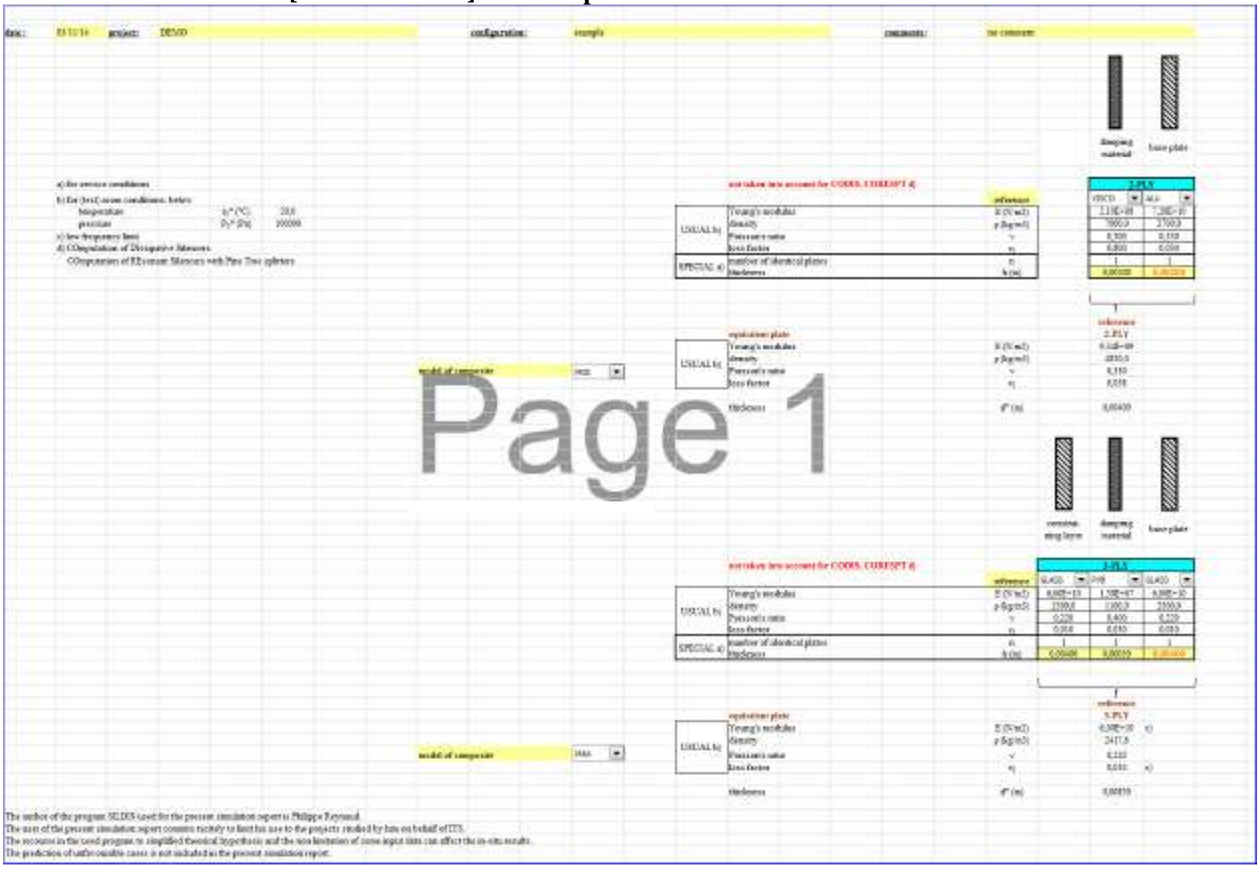
The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out CODAP] for example 2.4.4

Item	Cell for input	Foreseen action	Input	See placemark / comment
Reference	V17 to W17	Select a reference of material (in the proposed list) for each layer of interest	VISCO, ALU	[43],[45]
Thickness	V23 to W23	Input a real positive number	0.002;0.002	[44],[46]
Model of composite	L31	Select a model (in the proposed list)	MOI	[47]

Screenshots of the worksheets (for the example of computation)

Screenshot of worksheet [in-out CODAP] for example 2.4.4



Example 2.4.5 plate with a constrained damping

Envisaged application

It is foreseen to compute the engineering constants for a damped plate consisting of:

-1 GLASS plate [48] of thickness 4mm [49]
-1 viscoelastic plate (reference PVB in the database) [50] of thickness 0.5mm [51]
-1 GLASS plate [52] of thickness 4mm [53]

The model of composite MAX is considered [54]

Input data

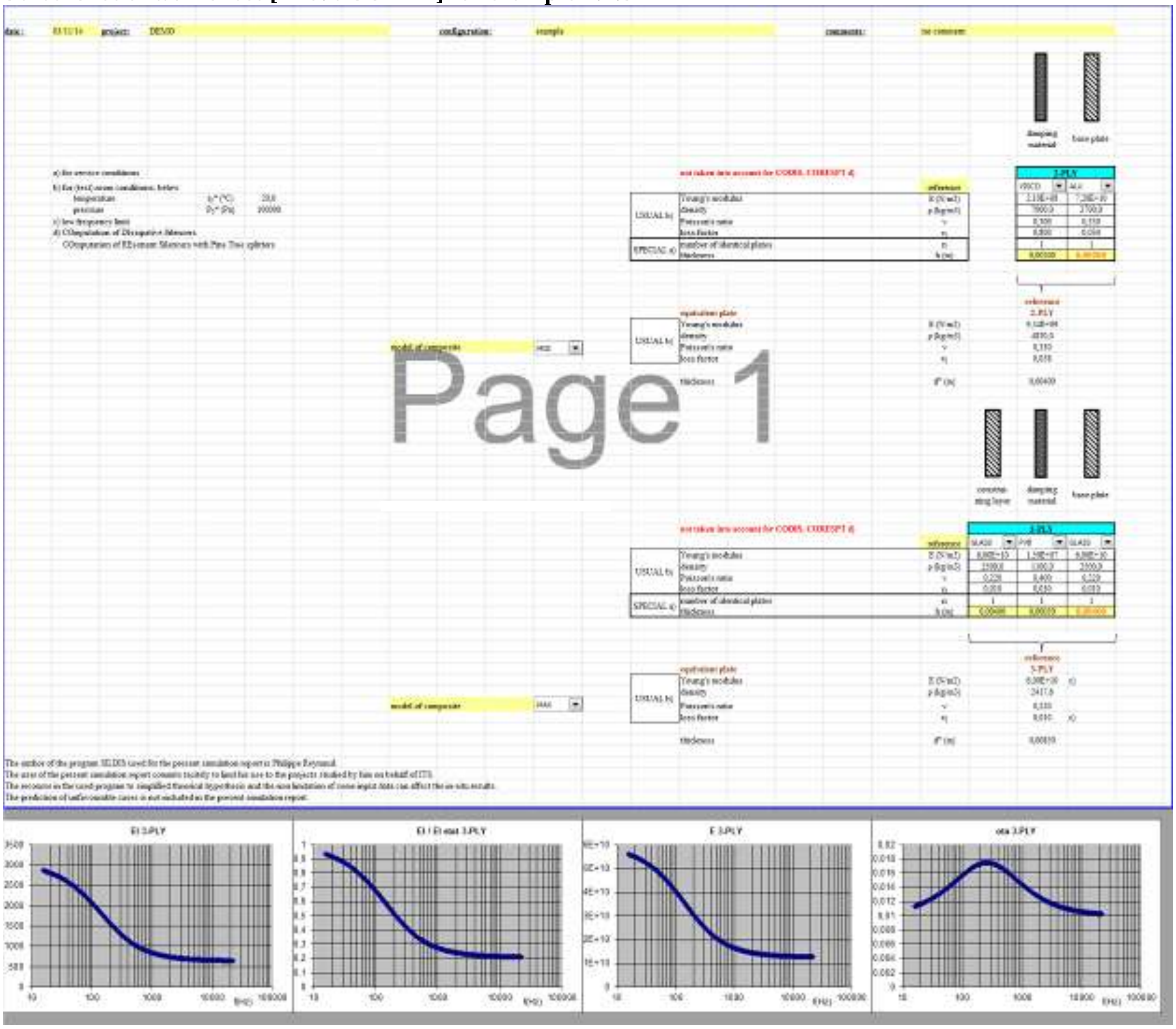
The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out CODAP] for example 2.4.5

Item	Cell for input	Foreseen action	Input	See placemark / comment
Reference	U48 to W48	Select a reference of material (in the proposed list) for each layer of interest	GLASS, PVB, GLASS	[48], [50], [52]
Thickness	U54 to W54	Input a real positive number	0.004,0.0005,0.004	[49], [51], [53]
Model of composite	L41	Select a model (in the proposed list)	MAX	[54]

Screenshots of the worksheets (for the example of computation)

Screenshot of worksheet [in-out CODAP] for example 2.4.5



Example 2.4.6 orthotropic plate

Envisaged application

It is foreseen to compute the engineering constants for a cladding [55] consisting of an aluminium plate [56] of thickness 1mm [57] with an overall thickness 30 mm [58] with a periodic length l=300 mm [59], with lengths of the corrugation T=b=100mm [60]. The model HAN [61] is considered.

Input data

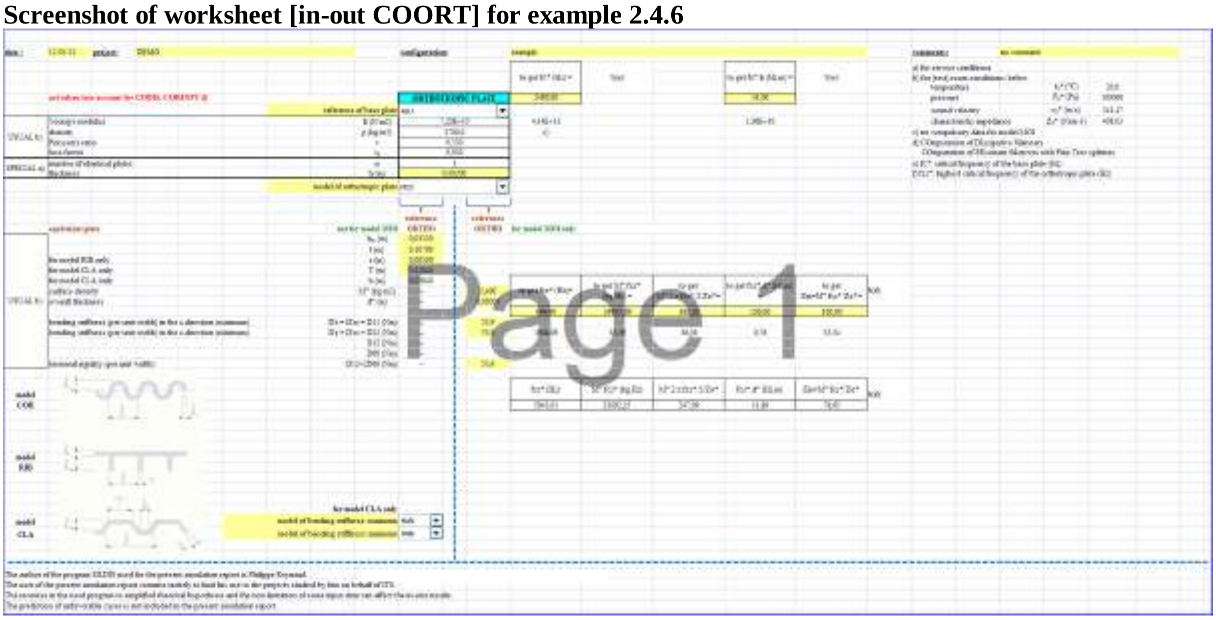
The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out COORT] for example 2.4.6

Item	Cell for input	Foreseen action	Input	See placemark / comment
Reference of base plate	L9	Select a reference of layer (in the proposed list) for each layer of interest	ALU	[56]
Thickness	J15	Input a real positive number	0.001	[57]
Model of orthotropic plate	J17	Select a model (in the proposed list)	CLA	[55]
hw	J23	Input a real positive number	0.03	[58]
l	J24	Input a real positive number	0.3	[59]
T	J26	Input a real positive number	0.1	[60]
Model of bending stiffness: maximum	J50	Select a model (in the proposed list)	for model CLA only	[61]
Model of bending stiffness: minimum	J51	Select a model (in the proposed list)	for model CLA only	[61]

<u>Screenshots of the worksheets (for the example of computation)</u>

Screenshot of worksheet [in-out COORT] for example 2.4.6



2.5: Illustrations of effects taken into account with SILDIS

Introduction

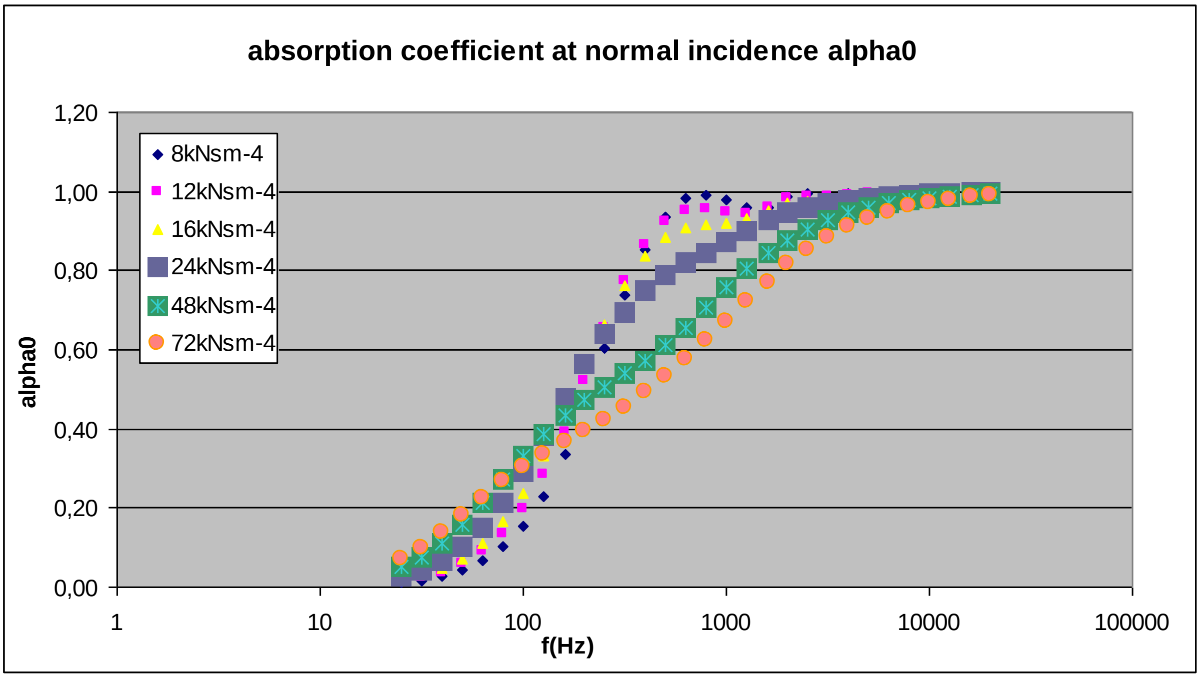
The prediction of acoustic performances of plane partitions with the software SILDIS is founded on a scientific and technical background as presented in § 2.2 of this user's manual, combining various knowledges in relation with physics. Some (future possible) users may not be perfectly familiar with some aspects of this background: in order to be anyway in a position of making the best use of this calculation tool, attention has to be paid by such users to some particular effects taken into account for the predictions thanks to illustrations given in this section of the user's manual. The intention is not to give a comprehensive list of the various effects of each parameter that may (alone or coupled with others) influence the acoustic performance of a partition, what would be very difficult to do. The goal is (thanks to examples): highlighting major key-points (considered separately) of the design of partitions, given some known laws of the physics, some of the input data being chosen in order to be as demonstrative as possible, given the plausible field of typical engineering applications.

All the numerical results below have been obtained using the software SILDIS with some post treatment for comparisons notably (some of those results can not be obtained by the user in the presented form for a sake of simplicity of the software).

Effects of the properties of a porous medium in a non-laminated lining (illustration 2.5.1)

Imput data: a lining is considered at (test) room pressure and temperature, (with an impervious rigid back), consisting of a single porous medium having (at room temperature) a flow resistivity in the direction normal to its surface **σy1** variable from 8 to 72 kNsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.1m. No series cloth is considered, no series perforated protection is considered.

Illustration of one of the effects: see below the prediction of the absorption coefficient at normal incidence depending on the flow resistivity of the porous medium (see key in the graph)



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
8kNsm-4	0,01	0,02	0,03	0,04	0,07	0,10	0,15	0,23	0,34	0,46	0,60	0,74	0,85	0,93	0,98
12kNsm-4	0,02	0,02	0,04	0,06	0,09	0,13	0,20	0,29	0,39	0,52	0,65	0,77	0,86	0,92	0,95
16kNsm-4	0,02	0,03	0,05	0,07	0,11	0,16	0,24	0,33	0,44	0,55	0,66	0,76	0,84	0,88	0,91
24kNsm-4	0,03	0,04	0,07	0,10	0,15	0,21	0,29	0,38	0,48	0,56	0,64	0,70	0,75	0,79	0,82
48kNsm-4	0,05	0,08	0,11	0,16	0,21	0,27	0,33	0,39	0,43	0,47	0,51	0,54	0,57	0,61	0,65
72kNsm-4	0,07	0,10	0,14	0,18	0,22	0,27	0,30	0,34	0,37	0,39	0,42	0,45	0,49	0,53	0,58

f1/3oct (Hz)	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
8kNsm-4	0,99	0,98	0,96	0,96	0,99	0,99	0,99	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
12kNsm-4	0,96	0,95	0,94	0,96	0,98	0,99	0,99	0,99	0,99	1,00	1,00	1,00	1,00	1,00	1,00
16kNsm-4	0,91	0,92	0,93	0,95	0,97	0,98	0,98	0,99	0,99	0,99	1,00	1,00	1,00	1,00	1,00
24kNsm-4	0,84	0,87	0,90	0,93	0,95	0,96	0,97	0,98	0,98	0,99	0,99	0,99	1,00	1,00	1,00
48kNsm-4	0,71	0,76	0,81	0,84	0,88	0,91	0,93	0,95	0,96	0,97	0,98	0,98	0,99	0,99	0,99
72kNsm-4	0,62	0,67	0,72	0,77	0,82	0,85	0,89	0,91	0,93	0,95	0,96	0,97	0,98	0,98	0,99

Comment: the choice of the flow resistivity of the porous medium influences sometimes considerably the acoustic performance of the lining (at least: for some frequencies). In particular, the choice of a flow resistivity of the porous medium too big compared with the optimum required - as far as acoustics is concerned - can lead to a degradation of the performance for frequencies possibly within the range of interest. This comment would also apply for the absorption coefficient for a statistic incidence.

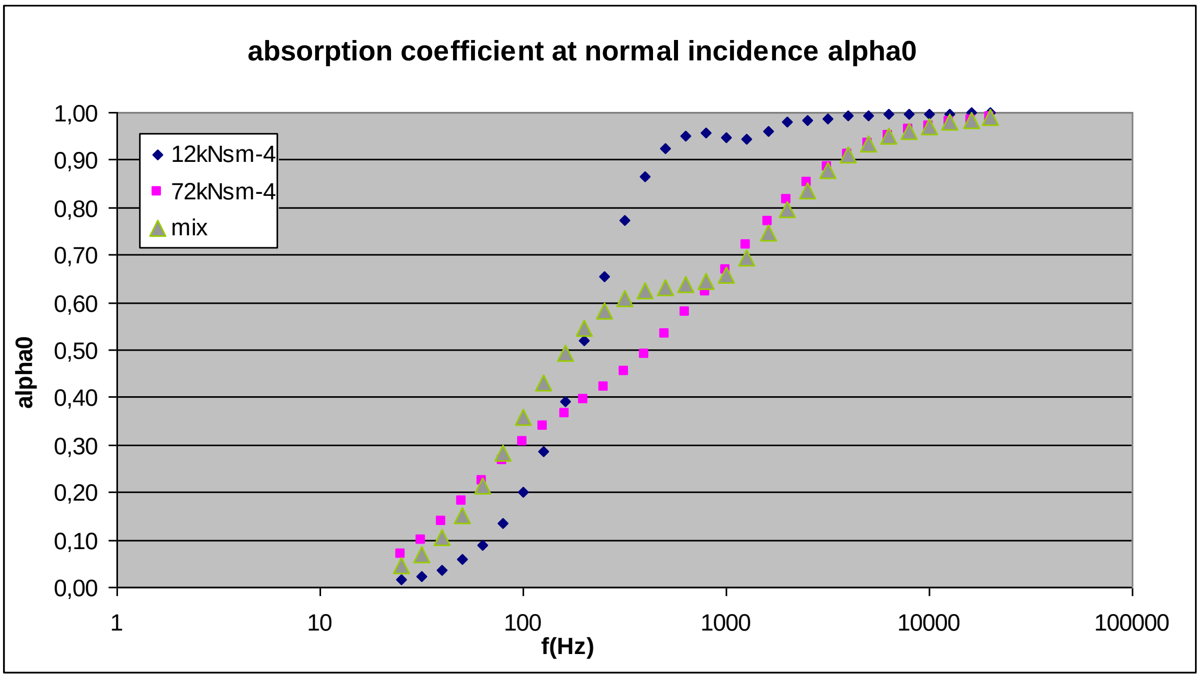
For a given porous medium, an increase of the density involves - generally speaking - an increase of the flow resistivity (everything else supposed to be equal): for example, **attention has to be paid to the consequences of the use (in some locations…) of high density rock wools using bonded short fibers producing possibly linings with a high flow resistance in some cases (especially when nothing is known regarding the properties of those materials in terms of flow resistivity, porosity…)**.

Effects of the properties of porous media in a laminated lining (illustration 2.5.2)

Imput data: a lining is considered at (test) room pressure and temperature (with an impervious rigid back), consisting of:

- a surface layer being a porous medium having (at room temperature) a flow resistivity in the direction normal to its surface **σy1**=72 kNsm-4, a porosity **ø**=0.95 (model M76), with a thickness **ds**=0.02m. No series cloth is considered, no series perforated protection is considered.
- a core layer being a porous medium having (at room temperature) a flow resistivity in the direction normal to its surface **σy1=**12 kNsm-4, a porosity **ø**=0.95 (model M76), with a thickness **dc**=0.08m. No series cloth is considered, no series perforated protection is considered.

Illustration of one of the effects: see below the prediction of the absorption coefficient at normal incidence of the mix (laminated lining) and the comparison with a non-laminated lining made (with a thickness **d**=**ds+dc**=0.10m) either 100 % of the material of the surface layer or 100 % of the material of the core layer (see key in the graph)



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
12kNsm-4	0,02	0,02	0,04	0,06	0,09	0,13	0,20	0,29	0,39	0,52	0,65	0,77	0,86	0,92	0,95
72kNsm-4	0,07	0,10	0,14	0,18	0,22	0,27	0,30	0,34	0,37	0,39	0,42	0,45	0,49	0,53	0,58
mix	0,05	0,07	0,10	0,15	0,21	0,28	0,36	0,43	0,49	0,54	0,58	0,61	0,62	0,63	0,64

f1/3oct (Hz)	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
12kNsm-4	0,96	0,95	0,94	0,96	0,98	0,99	0,99	0,99	0,99	1,00	1,00	1,00	1,00	1,00	1,00
72kNsm-4	0,62	0,67	0,72	0,77	0,82	0,85	0,89	0,91	0,93	0,95	0,96	0,97	0,98	0,98	0,99
mix	0,64	0,66	0,69	0,75	0,80	0,83	0,88	0,91	0,94	0,95	0,96	0,97	0,98	0,98	0,99

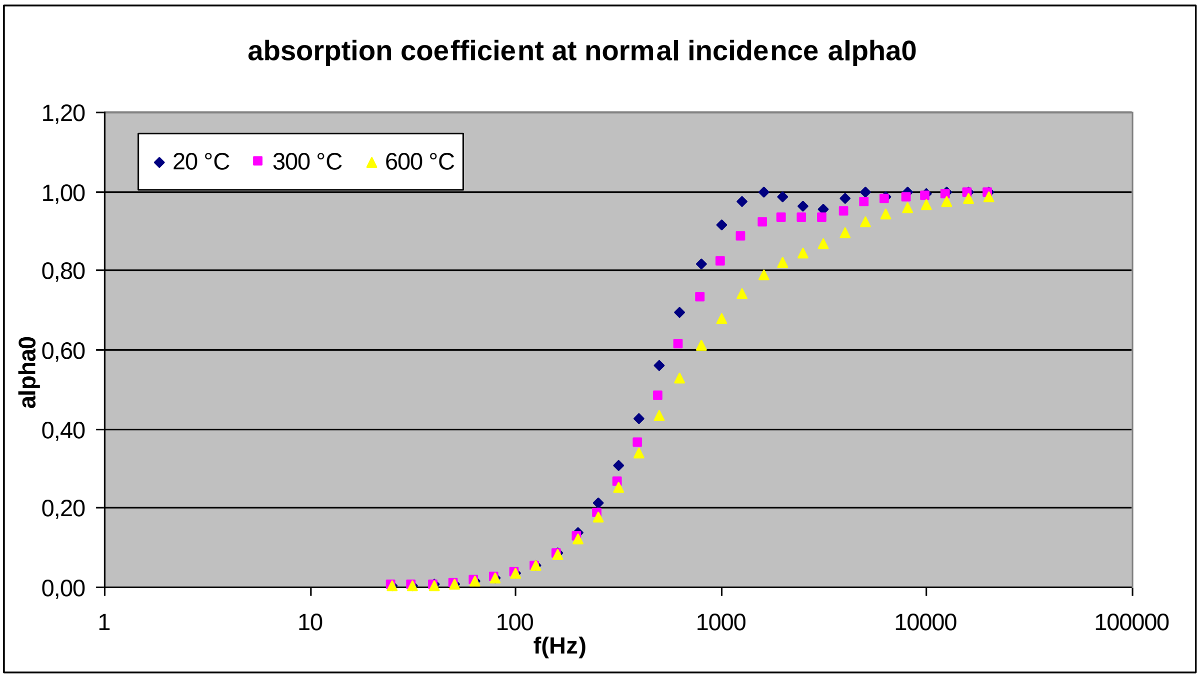
Comment: in case of a laminated lining, the choice of the flow resistivity of the porous media influences sometimes considerably the acoustic performance of the lining (at least: for some frequencies). In particular, the choice of a flow resistivity of the porous medium for the surface layer too big compared with the optimum required - as far as acoustics is concerned - can (even with a thickness small compared to the total thickness of the lining) lead to a degradation of the performance for frequencies possibly within the range of interest. This comment would also apply for the absorption coefficient for a statistic incidence.

See also the last paragraph of illustration 2.5.1

Effects of temperature (illustration 2.5.3)

Imput data: a lining is considered at (test) room pressure on the one hand at (test) room temperature and on the other hand at high temperature, (with an impervious rigid back), consisting of a single porous medium having (at room temperature) a flow resistivity in the direction normal to its surface **σy1=12400** Nsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.05m. No series cloth is considered, no series perforated protection is considered.

Illustration of one of the effects: see below the prediction of the absorption coefficient at normal incidence depending on the temperature (see key in the graph)



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500
20 °C	0,00	0,00	0,01	0,01	0,01	0,02	0,04	0,06	0,09	0,14	0,21	0,31	0,43	0,56
300 °C	0,00	0,00	0,01	0,01	0,01	0,02	0,03	0,05	0,08	0,12	0,18	0,26	0,36	0,48
600 °C	0,00	0,00	0,01	0,01	0,01	0,02	0,03	0,05	0,08	0,12	0,18	0,25	0,34	0,43

f1/3oct (Hz)	630	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
20 °C	0,70	0,82	0,92	0,98	1,00	0,99	0,96	0,96	0,98	1,00	0,99	1,00	1,00	1,00	1,00	1,00
300 °C	0,61	0,73	0,82	0,89	0,92	0,93	0,93	0,93	0,95	0,97	0,98	0,98	0,99	0,99	0,99	1,00
600 °C	0,53	0,61	0,68	0,74	0,79	0,82	0,84	0,87	0,90	0,92	0,95	0,96	0,97	0,98	0,98	0,99

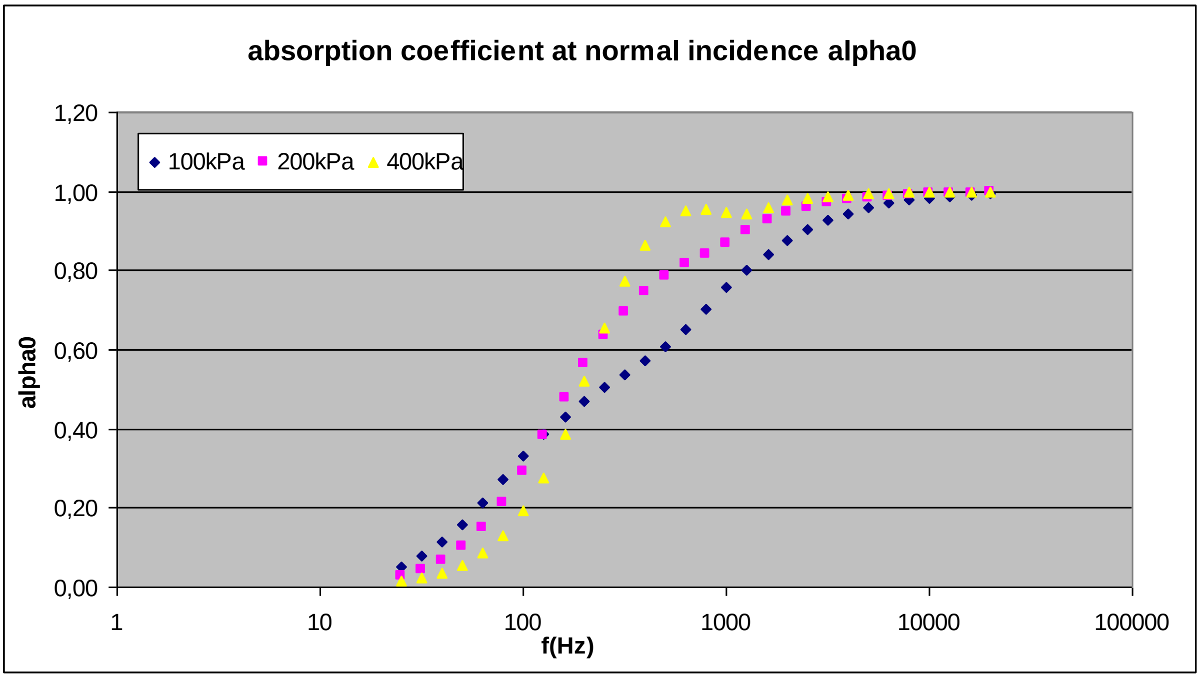
Comment: the temperature of the application influences sometimes considerably the acoustic performance of the lining (at least: for some frequencies). For a given material, an increase of the temperature involves - generally speaking - an increase of the flow resistivity (everything else supposed to be equal).In particular, the choice of a flow resistivity of the porous medium (at room temperature) too big compared with the optimum required (at the temperature of the application) - as far as acoustics is concerned - can lead to a degradation of the performance for frequencies possibly within the range of interest. This comment would also apply for the absorption coefficient for a statistic incidence.

See also the last paragraph of illustration 2.5.1

Effects of pressure (illustration 2.5.4)

Imput data: a lining is considered at (test) room temperature and at a pressure from 100 to 400kPa (with an impervious rigid back), consisting of a single porous medium having (at room temperature) a flow resistivity in the direction normal to its surface **σy1=48000** Nsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.1m. No series cloth is considered, no series perforated protection is considered.

Illustration of one of the effects: see below the prediction of the absorption coefficient at normal incidence depending on the pressure (see key in the graph)



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
100kPa	0,05	0,08	0,11	0,16	0,21	0,27	0,33	0,39	0,43	0,47	0,50	0,54	0,57	0,61	0,65
200kPa	0,03	0,04	0,07	0,10	0,15	0,21	0,29	0,38	0,48	0,56	0,64	0,69	0,75	0,79	0,82
400kPa	0,01	0,02	0,04	0,06	0,09	0,13	0,19	0,28	0,39	0,52	0,65	0,77	0,86	0,92	0,95

f1/3oct (Hz)	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
100kPa	0,70	0,76	0,80	0,84	0,88	0,90	0,93	0,94	0,96	0,97	0,98	0,98	0,99	0,99	0,99
200kPa	0,84	0,87	0,90	0,93	0,95	0,96	0,97	0,98	0,98	0,99	0,99	0,99	1,00	1,00	1,00
400kPa	0,95	0,95	0,94	0,96	0,98	0,98	0,99	0,99	0,99	1,00	1,00	1,00	1,00	1,00	1,00

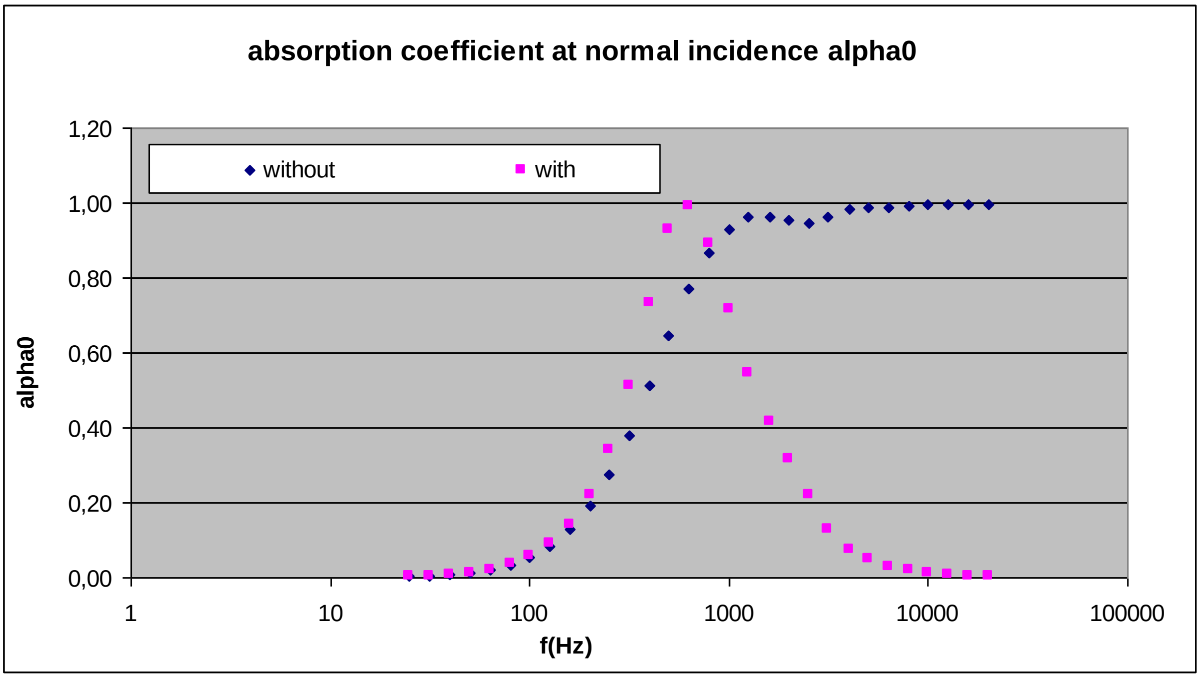
Comment: the pressure of the application influences sometimes considerably the acoustic performance of the lining (at least: for some frequencies). Depending on the frequency range of interest, absorbers with a higher flow resistivity may be selected in case of pressure lines. But the choice of a flow resistivity of the porous medium too big compared with the optimum required (at the pressure of the application) - as far as acoustics is concerned - can lead to a degradation of the performance for frequencies possibly within the range of interest. This comment would also apply for the absorption coefficient for a statistic incidence.

See also the last paragraph of illustration 2.5.1

Effects of a series cloth (illustration 2.5.5)

Imput data: a lining is considered at (test) room pressure and temperature, (with an impervious rigid back), consisting of a single porous medium homogeneous in directions parallel to and perpendicular to its surface, having a flow resistivity **σy**=22332Nsm-4, a porosity **ø**=0.95 (model M76) with a thickness **d**=0.05m. The cloth consists of an impervious membrane (surface density 125 g/m2)

Illustration of the effect: see below the prediction of the absorption coefficient at normal incidence without and with the cloth



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
without	0,00	0,01	0,01	0,01	0,02	0,04	0,05	0,08	0,13	0,19	0,27	0,38	0,51	0,65	0,77	0,87	0,93	0,96	0,96	0,95	0,95	0,96	0,98	0,99	0,99	0,99	0,99	1,00	1,00	1,00
with	0,00	0,01	0,01	0,01	0,02	0,04	0,06	0,09	0,14	0,22	0,34	0,51	0,73	0,93	0,99	0,89	0,72	0,55	0,42	0,32	0,22	0,13	0,08	0,05	0,03	0,02	0,01	0,01	0,00	0,00

Comment: the choice of a series cloth influences sometimes considerably the acoustic performance of the lining (at least: for some frequencies). In particular, the choice of a permeability of the cloth too small compared with the optimum required - as far as acoustics is concerned - can lead to a degradation of the performance for frequencies possibly within the range of interest (an increase of the performance being often obtained at low frequency due to the presence of a free vibrating foil).

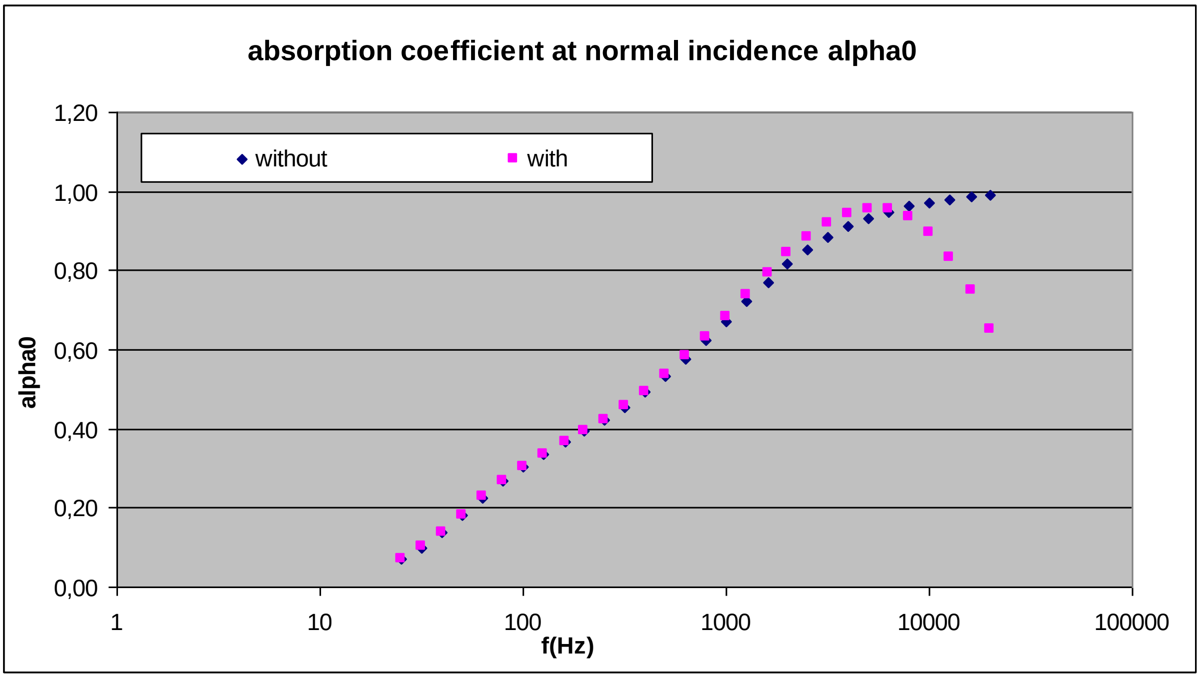
Attention has to be paid to the consequences of the use (in some locations…) of cloths producing possibly linings with a high flow resistance (especially when nothing is known regarding the properties of this materials in terms of flow resistivity, porosity…).

Attention has to be paid also to dust deposits in a position (in some cases) of involving effects comparable to the effect of a series cloth.

Effects of a series perforated protection (illustration 2.5.6)

Imput data: a lining is considered at (test) room pressure and temperature, (with an impervious rigid back),consisting of a single porous medium having a flow resistivity **σy**=72kNsm-4, a porosity **ø**=0.95 (model M76) with a thickness **d**=0.1m. The perforated protection consists of a sheet R3T5 (round holes with an hexagonal arrangement, diameter 3 mm, open area ratio **ε**=0.3265) of thickness 1 mm (general model MOI, model for the added impedances ROA)

Illustration of the effect: see below the prediction of the absorption coefficient at normal incidence without and with the perforated protection



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
without	0,07	0,10	0,14	0,18	0,22	0,27	0,30	0,34	0,37	0,39	0,42	0,45	0,49	0,53	0,58	0,62	0,67	0,72	0,77	0,82	0,85	0,89	0,91	0,93	0,95	0,96	0,97	0,98	0,98	0,99
with	0,07	0,10	0,14	0,18	0,23	0,27	0,31	0,34	0,37	0,39	0,42	0,46	0,49	0,54	0,58	0,63	0,68	0,74	0,79	0,84	0,89	0,92	0,94	0,96	0,96	0,94	0,90	0,83	0,75	0,65

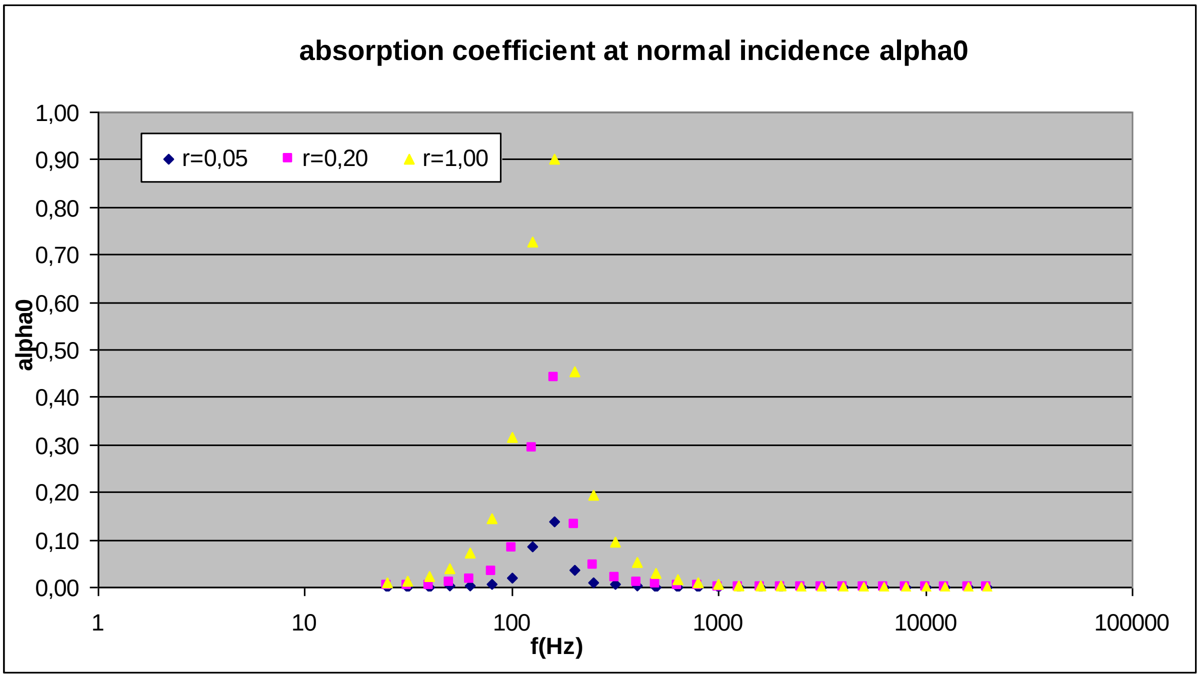
Comment: the choice of a perforated protection influences sometimes considerably the acoustic performance of the lining (at least: for some frequencies). For a given geometry of holes and a given thickness, a decrease of the open area ratio involves - generally speaking - a decrease of the performance. In particular, the choice of a perforated protection with an open area ratio too small compared with the optimum required - as far as acoustics is concerned - can lead to a degradation of the performance for frequencies possibly within the range of interest (in high frequency the performance is degraded in the example above despite a quite high open area ratio).

For a given perforated protection, the performance can decrease notably in case of a non-sufficiently pervious material at the rear: see also the last paragraph of illustration 2.5.1

Effects of membrane resonator (illustration 2.5.7)

Imput data: a membrane resonator is considered at (test) room pressure and temperature, consisting of an aluminium plate of thickness 0.0006 m installed in front of an rigid impervious back (distance **d**=0.1 m) accounted as a series cloth of infinite flow resistance. No porous medium (except air in the cavity) is considered, no series cloth (except the membrane) is considered, no series perforated protection is considered.

Illustration of one of the effects: see below the prediction of the absorption coefficient at normal incidence depending on a parallel resistance (normalized to the characteristic impedance of air r=Rp/Z0: see key in the graph) accounting for losses in relation with mounting conditions



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
r=0,05	0,00	0,00	0,00	0,00	0,00	0,01	0,02	0,09	0,14	0,04	0,01	0,01	0,00	0,00	0,00
r=0,20	0,00	0,00	0,00	0,01	0,02	0,03	0,08	0,29	0,44	0,13	0,05	0,02	0,01	0,01	0,00
r=1,00	0,01	0,01	0,02	0,04	0,07	0,14	0,32	0,73	0,90	0,45	0,20	0,10	0,05	0,03	0,02

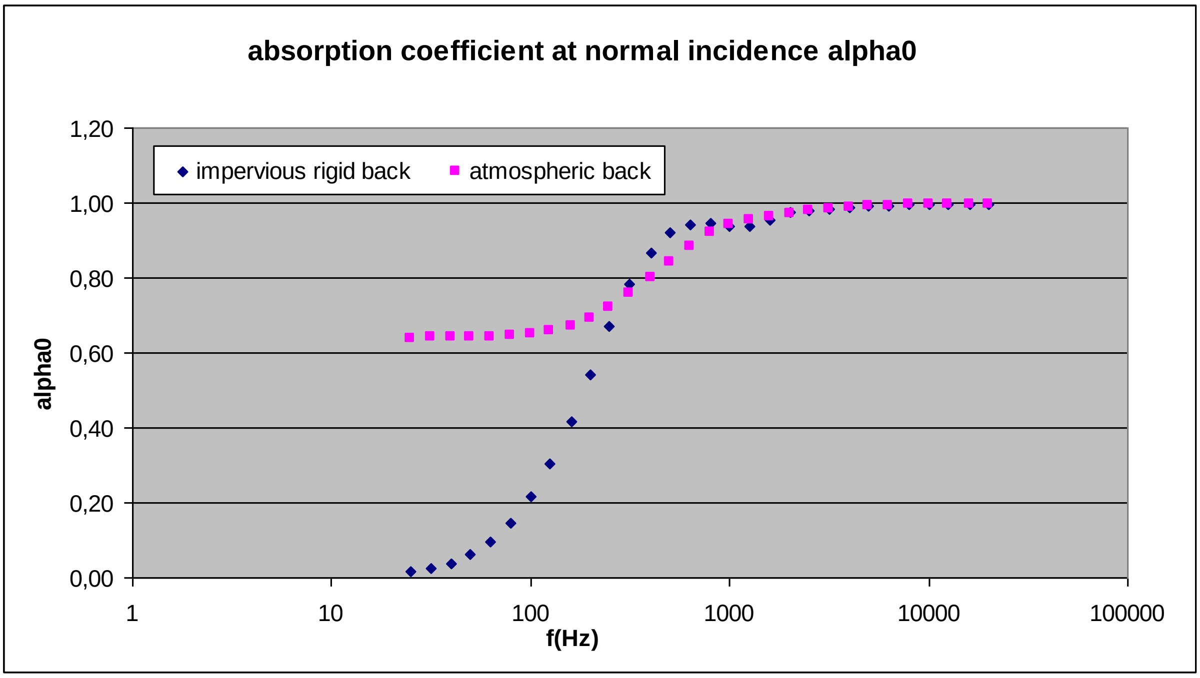
f1/3oct (Hz)	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
r=0,05	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
r=0,20	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
r=1,00	0,01	0,01	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00

Comment: the use of a membrane absorber allows an absorption coefficient at normal incidence in a very narrow frequency band. The choice of a parallel resistance accounting for losses in relation with mounting conditions influences sometimes considerably the acoustic performance (at least: for some frequencies). The way the membrane is fixed on site onto the cavity (limit conditions, properties of the interface), influencing the effective losses, differs of foreseenable cases (furthermore, the stiffness of the membrane itself is disregarded when accounted as a series cloth, what is not important only for sufficiently large plates). Due to those uncertainties, experimental determination of performances are required in the present status of the Art.

Effects of back (illustration 2.5.8)

Imput data: a lining is considered at (test) room pressure and temperature, consisting of a single porous medium having (at room temperature) a flow resistivity in the direction normal to its surface **σy1**=12.5 kNsm-4, a porosity **ø**=0.95 (model M76), with a thickness **d**=0.1m. A series cloth with a superficial flow resistance **Rs**=30 Nsm-3 and a surface density **ms**=0.090 kg/m2 is considered. No series perforated protection is considered.

Illustration of one of the effects: see below the prediction of the absorption coefficient at normal incidence depending on the backing of the porous medium (see key in the graph)



f1/3oct (Hz)	25	31,5	40	50	63	80	100	125	160	200	250	315	400	500	630
mpervious rigid back	0,02	0,03	0,04	0,06	0,10	0,15	0,22	0,31	0,42	0,54	0,67	0,78	0,87	0,92	0,94
atmospheric back	0,64	0,64	0,64	0,64	0,64	0,65	0,65	0,66	0,67	0,69	0,72	0,76	0,80	0,84	0,88

f1/3oct (Hz)	800	1k	1,25k	1,6k	2k	2,5k	3,15k	4k	5k	6,3k	8k	10k	12,5k	16k	20k
mpervious rigid back	0,94	0,94	0,94	0,96	0,98	0,98	0,98	0,99	0,99	0,99	0,99	0,99	1,00	1,00	1,00
atmospheric back	0,92	0,94	0,96	0,96	0,97	0,98	0,98	0,99	0,99	0,99	0,99	0,99	1,00	1,00	1,00

Comment: the choice of the backing influences sometimes considerably the acoustic performance of the lining (at least: for some frequencies). This comment would also apply for the absorption coefficient for a statistic incidence.

Attention has to be paid to the use of results obtained with an impervious rigid back (for example in an impedance tube or in a reverberant room) in case of on site atmospheric back.

Appendix to Section 2: list of symbols

General

Cf. corresponding § in Section 1

Partition

x: direction of highest bending stiffness
ILstat: insertion loss for a statistic incidence
lx : size of the partition along the x-direction (m)
lz : size of the partition along the z-direction (m)
Lx : length of the baffle in which the partition is symmetrically mounted along the x-direction (m)
Lz : width of the baffle in which the partition is symmetrically mounted along the z-direction (m)
Rdif: sound reduction index for a diffuse field
Rstat: sound reduction index for statistic incidence

α0: absorption coefficient for normal incidence
αstat: absorption coefficient for statistic incidence
αsab: Sabine's factor
φ: angle of orientation
φmin: minimum angle of orientation for angular integration
φmax: maximum angle of orientation for angular integration
θ : angle of incidence
θmin: minimum angle of incidence for angular integration
θmax: maximum angle of incidence for angular integration
τstat: transmission factor for statistic incidence

Plates

d''' : overall thickness (m)
D'x: highest bending stiffness per unit width (Nm)
D'z: lowest bending stiffness per unit width (Nm)
E: Young's modulus (N/m2)
fc: critical frequency for an isotropic plate (Hz) Note: superscript * for (test) room conditions
fceff: effective critical frequency for an isotropic plate (Hz) Note: superscript * for (test) room conditions
fcx: lowest critical frequency (Hz) Note: superscript * for (test) room conditions
fcz: upper critical frequency (Hz) Note: superscript * for (test) room conditions
f_{11}: frequence corresponding to the mode (1,1) of the plate (Hz)
M''': mass density (kg/m2)
w: lateral (transverse) displacement (m)

η : loss factor
ν : Poisson's coefficient
ρ : density (kg/m3)

Note: subscript i for set i

Perforated plates

ε: open area ratio

Miscellaneous

See also corresponding § in General considerations and in Section 1

page intentionally left blank

Section 3: computation of duct walls (MODULE 3 of the software)

3.1: Introduction

Terms and definitions

For the needs of the present user's manual, the following terms and definition apply:

No particular term or definition.

Mountings and geometry

The geometry used for the design of ducts with the program SILDIS is shown in figure 3.1

rectangular duct wall — cf. worksheet CORED

circular duct wall — cf. worksheet COCID

fig 3.1

Key of the previous figures

a: biggest (inner) dimension of the cross section of a rectangular duct
b: smallest (inner) dimension of the cross section of a rectangular duct
D: (inner) diameter of a rectangular duct

3.2: Scientific and technical background

The prediction of acoustic performances of ducts with SILDIS is founded on a scientific and technical background in relation with:

- analytical models for taking into account the properties of materials and various physical phenomena useful on the occasion of the computation
- measurement results for feeding some of those models and for allowing the necessary improvement (through correction factors) of the correlation between some calculations and on site observations

The obtained results are not comparable with standardized measurement due to the lack of such documents.

3.2.1Thermodynamics and fluid dynamics:

- **Steps of the computation**

Step [a]

All computations have been gathered in this single step for the sake of simplicity. See corresponding § in Section 1

3.2.2 Acoustics:

3.2.2.1 Acoustics: rectangular ducts

3.2.2.1.a Acoustics: rectangular ducts, break out noise

- **Bloc diagram for rectangular duct walls break out noise**

The computation scheme of rectangular duct walls is according the bloc-diagram below (cf. fig. 3.3):

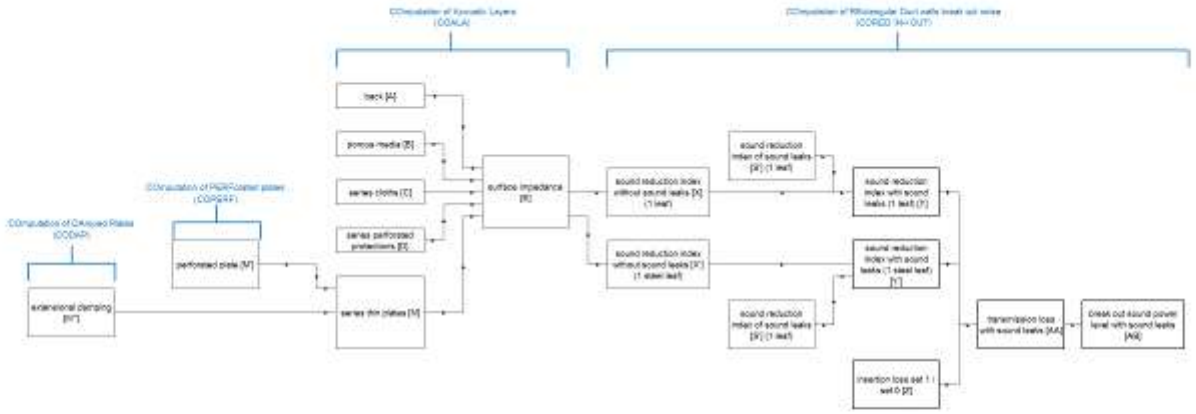


fig. 3.3

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRXX-015]

Note 2: the main steps (the steps involving a physical modeling) being referred to from [A] to [AB] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

- **Steps of the computation for rectangular duct walls break out noise**

Steps [A] to [V]

See corresponding § in Section 2, as far as sound reduction index of plates is concerned (used for step [X])

Preliminary remarks common to step [X] and step [X']

- ***Comments :***

  - the size of the cross section of the duct, the length of the duct, the flow rate are not related to the values selected in the worksheet [in-out COSIL] for B and H: corresponding input data are entered in worksheet [in-out CORED IN->OUT])

Step [X]

This step aims at calculating the **sound reduction index of a single-leaf (rectangular) duct made of 1 plate alone such as plates of set 0,** regardless of the selected quantity of such plates for set 0, regardless of the selected quantities of other elements, and with atmosphere at the front and at the rear regardless of the selected input data)

- ***Bibliography (references) :***

[X1] -	
[X2]	
[X3]	
[X4]	

- ***Comments :***

  - when used, the cut off frequency for the first higher mode **fco** is computed depending on the speed of sound **c**, the Mach number in the airways **M**, and the geometry of the duct, according to various models as shown in the table below:

model	**HAN**	MUN
source	[X1]	[X2]

  - the cross over frequency **fcr** is computed depending on the speed of sound **c**, the Mach number in the airways **M**, and the geometry of the duct, according to various models as shown in the table below:

model	HAN	NAS	**SMA**
source	[X1]	[X3]	[X4]

  - for f < fcr, the model of transmission (of sound) is selected as shown in the table below:

model	HAN	NAS	**SMA**
source	[X1]	[X3]	[X4]

  - for f > fcr, the model of transmission (of sound) is selected as shown in the table below:

model	HAN	NAS	**SMA**
source	[X1]	[X3]	[X4]

  - the model of minimum for Rdif is selected as shown in the table below:

model	HAN	ZER
source	[X1]	=0

  - the model of maximum for Rdif is selected as shown in the table below:

model	HAN	NAT
source	[X1]	(*)

* the sound reduction index is derived as for the general case

Step [X']

This step, being a complementary feature associated with step [X], aims at calculating the **sound reduction index of a single-leaf (rectangular) duct made of 1 steel plate alone with a thickness such as those of set 0,** regardless of the other selected parameters of such plates for set 0, regardless of the selected quantity of such plates for set 0, regardless of the selected quantities of other elements, and with atmosphere at the front and at the rear regardless of the selected input data)

- ***Bibliography (references) :***

[X'1]	
[X'2] -	

- ***Comments :***

  - the model of minimum for Rdif is selected as shown in the table below:

model	KOP	**NAT**
source	[X'2]	(*)

* the sound reduction index is derived as for the general case (cf. [X'1])

Step [Z]

This step aims at calculating the **insertion loss of set 1 when compared to set 0** with atmosphere at the front and at the rear regardless of the selected input data

- ***Bibliography (references) :***

[Z1]	

- ***Comments :***

  - the model of cover is selected as shown in the table below:

model	RIG	LIM
source	[Z1] RIG=RIGid	[Z1] LIM=LIMp

Step [AA]

This step aims at calculating the **transmission loss with sound leaks** with atmosphere at the front and at the rear regardless of the selected input data

- ***Bibliography (references) :***

No particular bibliography has been considered

- ***Comments :***

  - if IL stat is accounted TL out = R dif + IL stat else TL out = R dif

  - the model for Rdif is selected as shown in the table below:

model	1	2
source	cf. step [X]	cf. step [X']

Step [AB]

This step aims at calculating **the break out sound power level** with atmosphere at the front and at the rear regardless of the selected input data

First approach

- ***Bibliography (references) :***

[AB1]	
[AB2] -	

- ***Comments :***

  - the model for TL out is selected as shown in the table below:

model	2081	HAN	ASH
source	[AB1]	[AB2]	[AB2] (*)

*the correction factor to account for gradually decreasing values of the sound power level inside the duct as the distance from the sound source increases only accounts the sound attenuation Δ (dB/m) due to internal ductwork losses which is entered in worksheet [in-out CORED IN->OUT])

Second approach

○ ***Bibliography (references) :***

[AB3]	
[AB4] -	

○ ***Comments :***

- the model for TL out is selected as shown in the table below:

model	3733	MIX
source	[AB3]	[AB3](*)

*the way to account for gradually decreasing values of the sound power level inside the duct as the distance from the sound source increases is not as accounted with [AB3] (where is related to thermodynamics and frequency), being accounted by the means of the sound attenuation Δ (dB/m) due to internal ductwork losses as entered in worksheet [in-out CORED IN->OUT])

- the model for diffusivity factor Kd=Km is selected as shown in the table below:

model	SIN	3
source	[AB4]	=3

3.2.2.1.b Acoustics: rectangular ducts, break in noise

- **Bloc diagram for rectangular duct walls break in noise**

The computation scheme of rectangular duct walls is according the bloc-diagram below (cf. fig. 3.4):

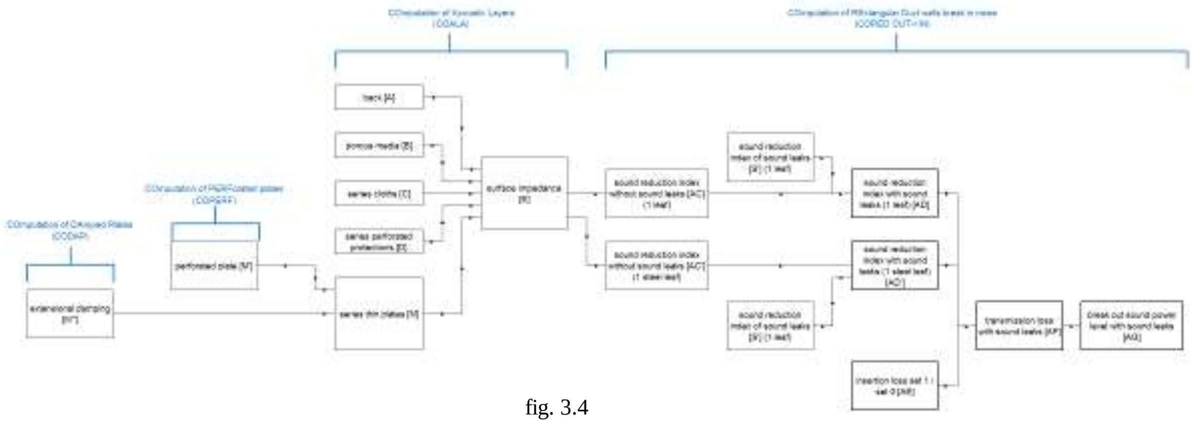


fig. 3.4

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRxx-015x]

Note 2: the main steps (the steps involving a physical modeling) being referred to from [A] to [AG] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

- **Steps of the computation for rectangular duct walls break in noise**

Steps [A] to [V]

See corresponding § in Section 2, as far as sound reduction index of plates is concerned (used for step [X])

Preliminary remarks common to step [AC] and step [AC']

- ***Comments :***
  - the size of the cross section of the duct, the length of the duct, the flow rate are not related to the values selected in the worksheet [in-out COSIL] for B and H: corresponding input data are entered in worksheet [in-out CORED IN->OUT])

Step [AC]

This step aims at calculating the **sound reduction index of a single-leaf (rectangular) duct made of 1 plate alone such as plates of set 0,** regardless of the selected quantity of such plates for set 0, regardless of the selected quantities of other elements, and with atmosphere at the front and at the rear regardless of the selected input data)

- ***Bibliography (references) :***

[AC1] -	
[AC2]	
[AC3]	
[AC4]	

- ***Comments :***
  - when used, the cut off frequency for the first higher mode **fco** is computed depending on the speed of sound **c**, the Mach number in the airways **M**, and the geometry of the duct, according to various models as shown in the table below:

model	**HAN**	MUN
source	[AC1]	[AC2]

  - the cross over frequency **fcr** is computed depending on the speed of sound **c**, the Mach number in the airways **M**, and the geometry of the duct, according to various models as shown in the table below:

model	HAN	NAS	SMA
source	[AC1]	[AC3]	[AC4](*)

*[AC4] seems to be in error

Step [AC']

This step, being a complementary feature associated with step [X], aims at calculating the **sound reduction index of a single-leaf (rectangular) duct made of 1 steel plate alone with a thickness such as those of set 0,** regardless of the other selected parameters of such plates for set 0, regardless of the selected quantity of such plates for set 0, regardless of the selected quantities of other elements, and with atmosphere at the front and at the rear regardless of the selected input data

- ***Bibliography (references) :***

[AC'1]	
[AC'2] -	

- ***Comments :***
  - the model of ratio a/b is selected as shown in the table below – whatever the corresponding input data of a and b are

model	1	2	4
source	a/b=1	a/b=2	a/b=4

Step [AE]

This step aims at calculating the **insertion loss of set 1 when compared to set 0** with atmosphere at the front and at the rear regardless of the selected input data

- ***Bibliography (references) :***

[AE1]	

- ***Comments :***
  - Cf. step [Z]

Step [AF]

This step aims at calculating the **transmission loss with sound leaks** with atmosphere at the front and at the rear regardless of the selected input data

- ***Bibliography (references) :***

No particular bibliography has been considered

- ***Comments :***
  - if IL stat is accounted TL out = R dif + IL stat else TL out = R dif
  - the model for Rdif is selected as shown in the table below:

model	1	2
source	cf. step [AC]	cf. step [AC']

Step [AG]

This step aims at calculating **the break in sound power level** with atmosphere at the front and at the rear regardless of the selected input data

- ***Bibliography (references) :***

[AG1]	
[AG2] -	

- ***Comments :***
  - the model for TL out is selected as shown in the table below:

model	2081	HAN
source	[AG1]	[AG2]

3.2.2.2 Acoustics: circular ducts

3.2.2.2.a Acoustics: circular ducts, break out noise

- **Bloc diagram for circular duct walls break out noise**

The computation scheme of circular duct walls is according the bloc-diagram below (cf. fig. 3.5):

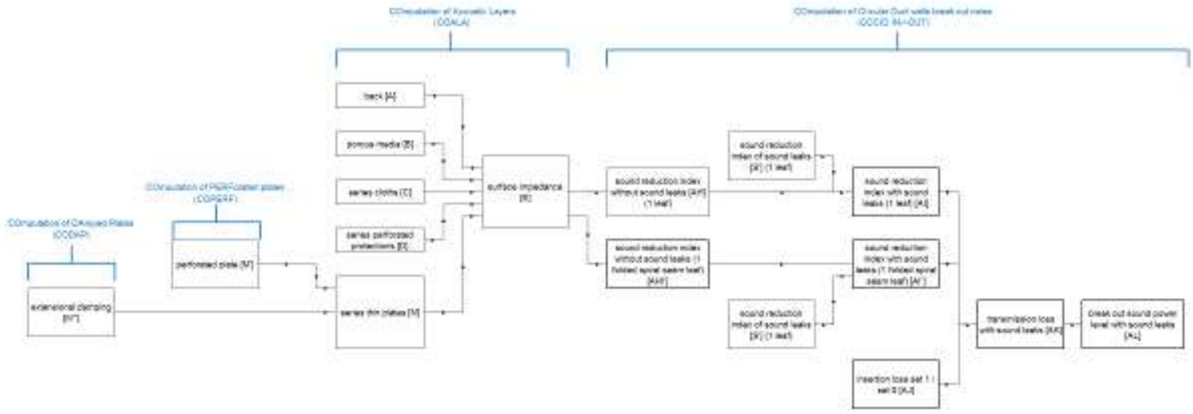


fig. 3.5

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRxx-015x]

Note 2: the main steps (the steps involving a physical modeling) being referred to from [A] to [AL] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

▪ Steps of the computation for circular duct walls break out noise

Steps [A] to [V]

See corresponding § in Section 2, as far as sound reduction index of plates is concerned (use to be précised on the occasion of a future revision of this user's manual)

Preliminary remarks common to step [AH] and step [AH']

- ***Comments :***
  - the size of the cross section of the duct, the length of the duct, the flow rate are not related to the values selected in the worksheet [in-out COSIL] for D: corresponding input data are entered in worksheet [in-out COCID IN->OUT])

Step [AH]

This step aims at calculating the **sound reduction index of a single-leaf (circular) duct made of 1 layer alone such as plates of set 0,** regardless of the selected quantity of such plates for set 0, regardless of the selected quantities of other elements, and with atmosphere at the front and at the rear regardless of the selected input data)

- ***Bibliography (references) :***

[AH1] -	
[AH2]	
[AH3]	

- ***Comments :***
  - when used, the cut off frequency for the first higher mode **fco** is computed depending on the speed of sound **c**, the Mach number in the airways **M**, and the geometry of the duct, according to various models as shown in the table below:

model	**HAN**	MUN
source	[AH1]	[AH2]

  - the model of mounting is selected as shown in the table below:

model	mounting (source [AH3])
a)	welded pipe with an average of one bend per approximately 20D length
b)	welded straight pipe from approximately 20D length behind the source
c)	welded, average value from a) and b), if not to be specified more precisely
d)	as b) but pipe flanged at a distance from 2m to 6m
e)	pipe up to approximately 20D length behind the valve with customary solid-borne sound coupling between valve and flanged pipe

Step [AH']

This step, being a complementary feature associated with step [X], aims at calculating the **sound reduction index of a single-leaf (circular) folded-spiral seam duct made of 1 layer alone such as plates of set0,** regardless of the selected quantity of such plates for set 0, regardless of the selected quantities of other elements, and with atmosphere at the front and at the rear regardless of the selected input data)

- ***Bibliography (references) :***

[AH'1] -	
[AH'2]	
[AH'3]	
[AH'4] -	

Comments :

- when used, the cut off frequency for the first higher mode **fco** is computed depending on the speed of sound **c**, the Mach number in the airways **M**, and the geometry of the duct, according to various models as shown in the table below:

model	**HAN**	MUN
source	[AH'1]	[AH'2]

- when used, the annular expansion frequency fRokt is selected as shown in the table below:

model	**NAT**	OCT
source	(*)	[AH'3]

* the annular expansion frequency is derived as for the general case (i.e.: not converted in 1/1 octave central frequency)

- the model of HF (High Frequency) limitation is selected as shown in the table below:

model	2081	**MOI**
source	[AH'3]	(*)

* the HF limitation is derived as a corrected value

Step [AJ]

This step aims at calculating the **insertion loss of set 1 when compared to set 0** with atmosphere at the front and at the rear regardless of the selected input data

- ***Bibliography (references) :***

[AJ1] -	

- ***Comments :***

  - the model of insertion loss is selected as shown in the table below:

model	HAL	MIC
source	[AJ1] HAL=HALe	[AJ1] MIC=MIChelsen

Step [AK]

This step aims at calculating the **transmission loss with sound leaks** with atmosphere at the front and at the rear regardless of the selected input data

- ***Bibliography (references) :***

No particular bibliography has been considered

- ***Comments :***

  - if IL stat is accounted TL out = R dif + IL stat else TL out = R dif

  - the model for Rdif is selected as shown in the table below:

model	1	2
source	cf. step [AH]	cf. step [AH']

Step [AL]

This step aims at calculating **the break out sound power level** with atmosphere at the front and at the rear regardless of the selected input data

First approach

- ***Bibliography (references) :***

[AL]	
[AL2] -	

- ***Comments :***

  - the model for TL out is selected as shown in the table below:

model	2081	HAN	ASH
source	[AL]	[AL2]	[AL2] (*)

*the correction factor to account for gradually decreasing values of the sound power level inside the duct as the distance from the sound source increases only accounts the sound attenuation Δ (dB/m) due to internal ductwork losses which is entered in worksheet [in-out COCID IN->OUT])

Second approach

- ***Bibliography (references) :***

[AL3]	
[AL4] -	

- ***Comments :***

  - the model for TL out is selected as shown in the table below:

model	3733	MIX
source	[AL3]	[AL3](*)

*the way to account for gradually decreasing values of the sound power level inside the duct as the distance from the sound source increases is not as accounted with [AL3] (where is related to thermodynamics and frequency), being accounted by the means of the sound attenuation Δ (dB/m) due to internal ductwork losses as entered in worksheet [in-out COCID IN->OUT])

  - the model for diffusivity factor Kd=Km is selected as shown in the table below:

model	SIN	3
source	[AL4]	=3

3.2.2.2.b Acoustics: circular ducts, break in noise

- **Bloc diagram for circular duct walls break in noise**

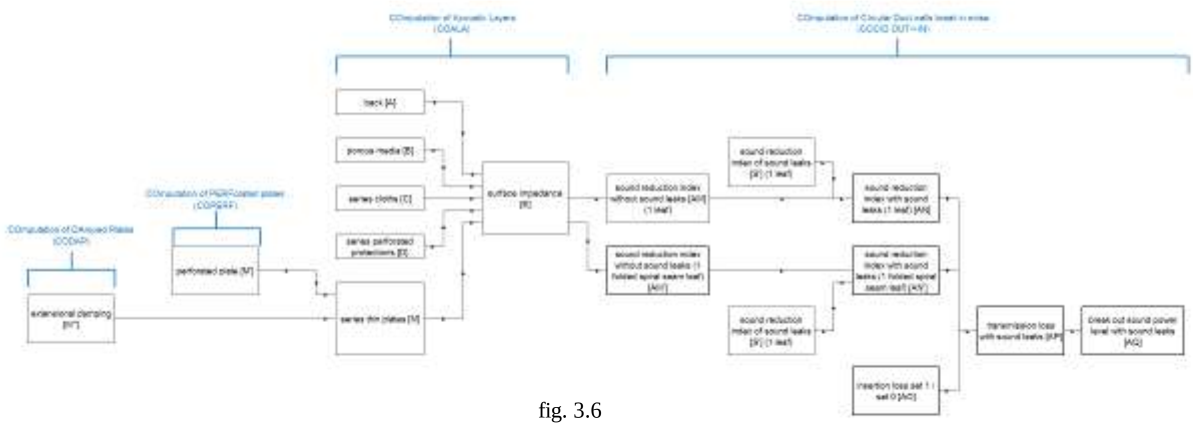


fig. 3.6

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRxx-015x]

Note 2: the main steps (the steps involving a physical modeling) being referred to from [A] to [AQ] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

- **Steps of the computation for circular duct walls break in noise**

Steps [A] to [V]

See corresponding § in Section 2, as far as sound reduction index of plates is concerned (use to be précised on the occasion of a future revision of this user's manual)

Preliminary remarks common to step [AP] and step [AQ]

- ***Comments :***

  - the size of the cross section of the duct, the length of the duct, the flow rate are not related to the values selected in the worksheet [in-out COSIL] for D: corresponding input data are entered in worksheet [in-out COCID IN->OUT])

Step [AP]

This step aims at calculating the **transmission loss with sound leaks** with atmosphere at the front and at the rear regardless of the selected input data

- ***Bibliography (references) :***

  No particular bibliography has been considered

- ***Comments :***

  - if IL stat is accounted TL out = R dif + IL stat else TL out = R dif
  - the model for Rdif is selected as shown in the table below:

model	1	2
source	cf. step [AN]	cf. step [AN']

Step [AQ]

This step aims at calculating **the break out sound power level** with atmosphere at the front and at the rear regardless of the selected input data

- ***Bibliography (references) :***

[AQ1]	
[AQ2] -	

- ***Comments :***

  - the model for TL out is selected as shown in the table below:

model	2081	HAN
source	[AB1]	[AB2]

3. 3: How to use SILDIS

Operating conditions / security level / safety

See corresponding § in the chapter **General considerations**

For safety reasons, some cells of the original file provided to the user (as mentioned in the table below) for which input data are foreseen to be entered by the user are pre-filled with the value "1/0", among the yellow cells for which the color orange is used (*).

Worksheet	Cells
[in COALA]	E13, J37, W38
[in CODAP]	W23
[in-out COPPA]	X53, X54 (**)

* something like that

** attention has to be paid to the fact that the considered sheet is not included in the worksheets listed below

Worksheets

Regarding the COmputation of Duct Walls, the software SILDIS is configurated in order to allow the user to access to various worksheets being linked as shown in fig.3.5 (the overview of the worksheets being shown in table below).

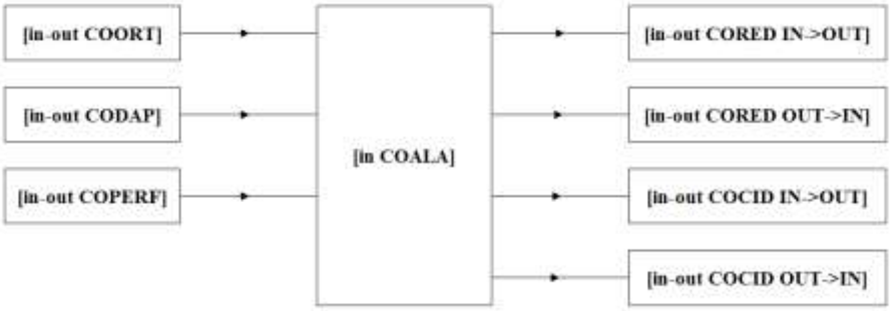


Fig. 3.5

Note: a partly common background is required for several steps of the computation schemes of different acoustic components (insertion loss of a silencer, absorption coefficient / sound reduction index of a plane partition, sound reduction index of a duct wall...). For this reason worksheets [in COALA] and [in COSIL] are distinct due to the existence of other calculations (by the means of SILDIS) using the routine COALA (COmputation of Acoustic LAyers) but <u>not</u> using the routine COSIL (COmputation of SILencers).

Worksheet	Suitable for mountings	Input data	Results
[in COALA]	all	for sets, for reference spectrum	--
[in-out CORED IN->OUT]	REctangular Duct, break out transmission	for duct: dimensions, flow rate	indicators of performance (acoustics)
[in-out CORED OUT->IN]	REctangular Duct, break in transmission		
[in-out COCID IN->OUT]	CIrcular Duct, break out transmission	for duct: dimensions, flow rate	
[in-out COCID OUT->IN]	CIrcular Duct, break in transmission		

<u>Input data, alerts and results: the key points</u>

The best use of the software requires the knowledge of some key points in relation with:

- the **<u>input data</u>**

  See corresponding § in the chapter **General considerations**

  As far as plates (to which the layer of material of the considered wall is equal) are concerned, specific data bases (libraries) (will) allow the design to be made with in-built engineering data (constants) referred to as "Usual" in the worksheets of the software. Warning: some properties of the presently referenced materials still not have been checked by reliable sources. See also report [PhRxx-015x] Collection of soundproofing constructions systems: a companion to "User's manual for the software SILDIS"

  - **<u>data base (library) for thin plates (available in worksheet in COALA)</u>**

    - ✓ contents of the library: **21 possible references of material layers**
    - ✓ among those references: 2-PLY (reported from worksheet CODAP)

  - **<u>data base (library) for layers constituting the damped plates (available in worksheet in CODAP)</u>**

    - ✓ contents of the library: **21 possible references of material layers**

- some **<u>alerts</u>** in case of input data involving a warning of the user
- the place where (and the way) some **<u>results</u>** are presented

Those key points are reviewed worksheet per worksheet hereafter: the cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out CORED IN->OUT]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Biggest dimension a	AH49	Input a positive real	
Smallest dimension b	AH50	Input a positive real	
Length L	AH51	Input a positive real	
Mass flow rate	AH53	Input a positive real	
Model of cut-off frequency fco	AH64	Select a model (in the proposed list)	
Model of cross over frequency fcr	R81	Select a model (in the proposed list)	
For f<fcr model of transmission	R85	Select a model (in the proposed list)	
For f>fcr model of transmission	R90	Select a model (in the proposed list)	
Model of minimum for Rdif	R95	Select a model (in the proposed list)	
Model of maximum for Rdif	R99	Select a model (in the proposed list)	
Model of minimum for Rdif	R108	Select a model (in the proposed list)	
Model	R131	Select a model (in the proposed list)	
Limitation of IL for HF	R133	Input a positive real	Limitation of Insertion Loss for High Frequency
Model for Rdif	R149	Select a model (in the proposed list)	1= first approach displayed in the same worksheet 2= second approach displayed in the same worksheet
Accounting IL stat (0/1)	R151	For NO input 0, for YES input 1	
Δ (dB / m)	AB154 to AL154	Input a positive real	
model	R158	Select a model (in the proposed list)	
model	R164	Select a model (in the proposed list)	
Model for diffusivity factor Kd=Km	R168	Select a model (in the proposed list)	
Length of duct	R172	Input a positive real	

- ***Main displays of the results :***

Tables of results and graphs for a rectangular duct: 1 plate alone such as those of set 0

- **break out sound reduction index**: see lines 75 to 100 (columns AA to AN)

Tables of results and graphs for a rectangular duct: 1 steel plate alone, thickness such as those of set 0

- **break out sound reduction index**: see lines 102 to 123 (columns AA to AN)

Tables of results and graphs for a rectangular duct: set 1/ set 0: coupling 0%

- **insertion loss**: see lines 125 to 145 (columns AA to AN)

Tables of results for a rectangular duct: TL out = Rdif +? ILstat

- **break out transmission loss**: see lines 147 to 151 (columns AA to AN)

Tables of results for a rectangular duct: Lw out

- **break out sound power level**: see lines 156 to 160 (columns AA to AN)

Tables of results for a rectangular duct: Lw out

- **break out sound power level**: see lines 162 to 166 (columns AA to AN)

Worksheet [in-out CORED OUT->IN]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Model of cross over frequency fcr	X81	Select a model (in the proposed list)	
Model of ratio a/b	X113	Select a model (in the proposed list)	
Model for Rdif	X149	Select a model (in the proposed list)	1= first approach displayed in the same worksheet 2= second approach displayed in the same worksheet
Accounting IL stat (0/1)	X151	For NO input 0, for YES input 1	
model	X158	Select a model (in the proposed list)	

- ***Main displays of the results :***

Tables of results and graphs for a rectangular duct: 1 plate alone such as those of set 0

- **break in sound reduction index**: see lines 75 to 100 (columns AA to AN)

Tables of results and graphs for a rectangular duct: 1 steel plate alone, thickness such as those of set 0

- **break in sound reduction index**: see lines 102 to 123 (columns AA to AN)

Tables of results and graphs for a rectangular duct: set 1/ set 0: coupling 0%

- **insertion loss**: see lines 125 to 145 (columns AA to AN)

Tables of results for a rectangular duct: TL out = Rdif +? ILstat

- **break in transmission loss**: see lines 147 to 151 (columns AA to AN)

Tables of results for a rectangular duct: Lw out

- **break in sound power level**: see lines 156 to 160 (columns AA to AN)

Tables of results for a rectangular duct: Lw out

- **break in sound power level**: see lines 162 to 166 (columns AA to AN)

Worksheet [in-out COCID IN->OUT]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Diameter D	AH49	Input a positive real	
Length L	AH51	Input a positive real	
Mass flow rate	AH53	Input a positive real	
Model of cut-off frequency fco	AH64	Select a model (in the proposed list)	
Model of mounting	R85	Select a model (in the proposed list)	
Model of annular expansion frequency fRokt	R108	Select a model (in the proposed list)	
Model of HF limitation	R113	Select a model (in the proposed list)	
Model	R131	Select a model (in the proposed list)	
Model for Rdif	R149	Select a model (in the proposed list)	1= first approach displayed in the same worksheet 2= second approach displayed in the same worksheet
Accounting IL stat (0/1)	R151	For NO input 0, for YES input 1	
Δ (dB / m)	AB154 to AL154	Input a positive real	
model	R158	Select a model (in the proposed list)	
model	R164	Select a model (in the proposed list)	
Model for diffusivity factor Kd=Km	R168	Select a model (in the proposed list)	
Length of duct	R172	Input a positive real	

- ***Main displays of the results :***

Tables of results and graphs for a rectangular duct: 1 plate alone such as those of set 0

- **break out sound reduction index**: see lines 75 to 100 (columns AA to AN)

Tables of results and graphs for a rectangular duct: 1 steel plate alone, thickness such as those of set 0

- **break out sound reduction index**: see lines 102 to 123 (columns AA to AN)

Tables of results and graphs for a rectangular duct: set 1/ set 0: coupling 0%

- **insertion loss**: see lines 125 to 145 (columns AA to AN)

Tables of results for a rectangular duct: TL out = Rdif +? ILstat

- **break out transmission loss**: see lines 147 to 151 (columns AA to AN)

Tables of results for a rectangular duct: Lw out

- **break out sound power level**: see lines 156 to 160 (columns AA to AN)

Tables of results for a rectangular duct: Lw out

- **break out sound power level**: see lines 162 to 166 (columns AA to AN)

Worksheet [in-out COCID OUT->IN]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Model for Rdif	X149	Select a model (in the proposed list)	1= first approach displayed in the same worksheet 2= second approach displayed in the same worksheet
Accounting IL stat (0/1)	X151	For NO input 0, for YES input 1	
model	X158	Select a model (in the proposed list)	

- ***Main displays of the results :***

Tables of results and graphs for a rectangular duct: 1 plate alone such as those of set 0

- **break in sound reduction index**: see lines 75 to 100 (columns AA to AN)

Tables of results and graphs for a rectangular duct: 1 steel plate alone, thickness such as those of set 0

- **break in sound reduction index**: see lines 102 to 123 (columns AA to AN)

Tables of results and graphs for a rectangular duct: set 1/ set 0: coupling 0%

- **insertion loss**: see lines 125 to 145 (columns AA to AN)

Tables of results for a rectangular duct: TL out = Rdif +? ILstat

- **break in transmission loss**: see lines 147 to 151 (columns AA to AN)

Tables of results for a rectangular duct: Lw out

- **break in sound power level**: see lines 156 to 160 (columns AA to AN)

Tables of results for a rectangular duct: Lw out

- **break in sound power level**: see lines 162 to 166 (columns AA to AN)

3.4: Examples of computation with SILDIS

Example 3.4.1 rectangular duct wall

Envisaged application

It is wished to compute the breakout transmission loss of a rectangular duct wall for room conditions. The duct is made of steel [1] with a thickness 0.567 mm [2]. A cross section B=151 mm [3]*H=151 mm [4] is considered. Regarding models of computation: the procedures of the model referred to as SMA are selected [5].

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA]

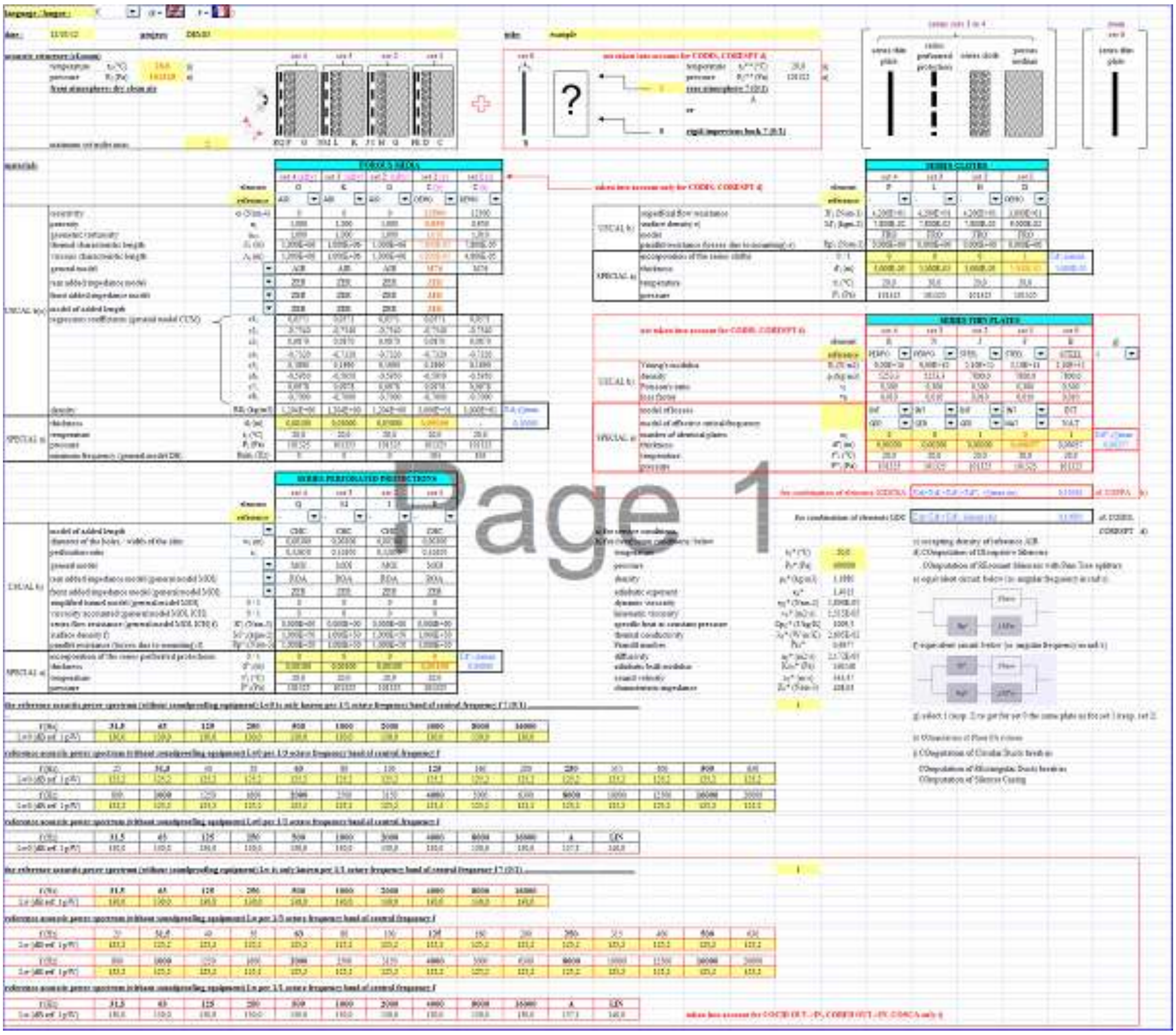
Item	Cell for input	Foreseen action	Input	See placemark / comment
Reference	W31	Select a reference (material in the proposed list)	STEEL	[1]
g)	Y31	Select 1 or 2 in the proposed list	1	
Thickness	W38	Input a real positive number	0.567E-3	[2]

Worksheet [in-out CORED1 IN->OUT]

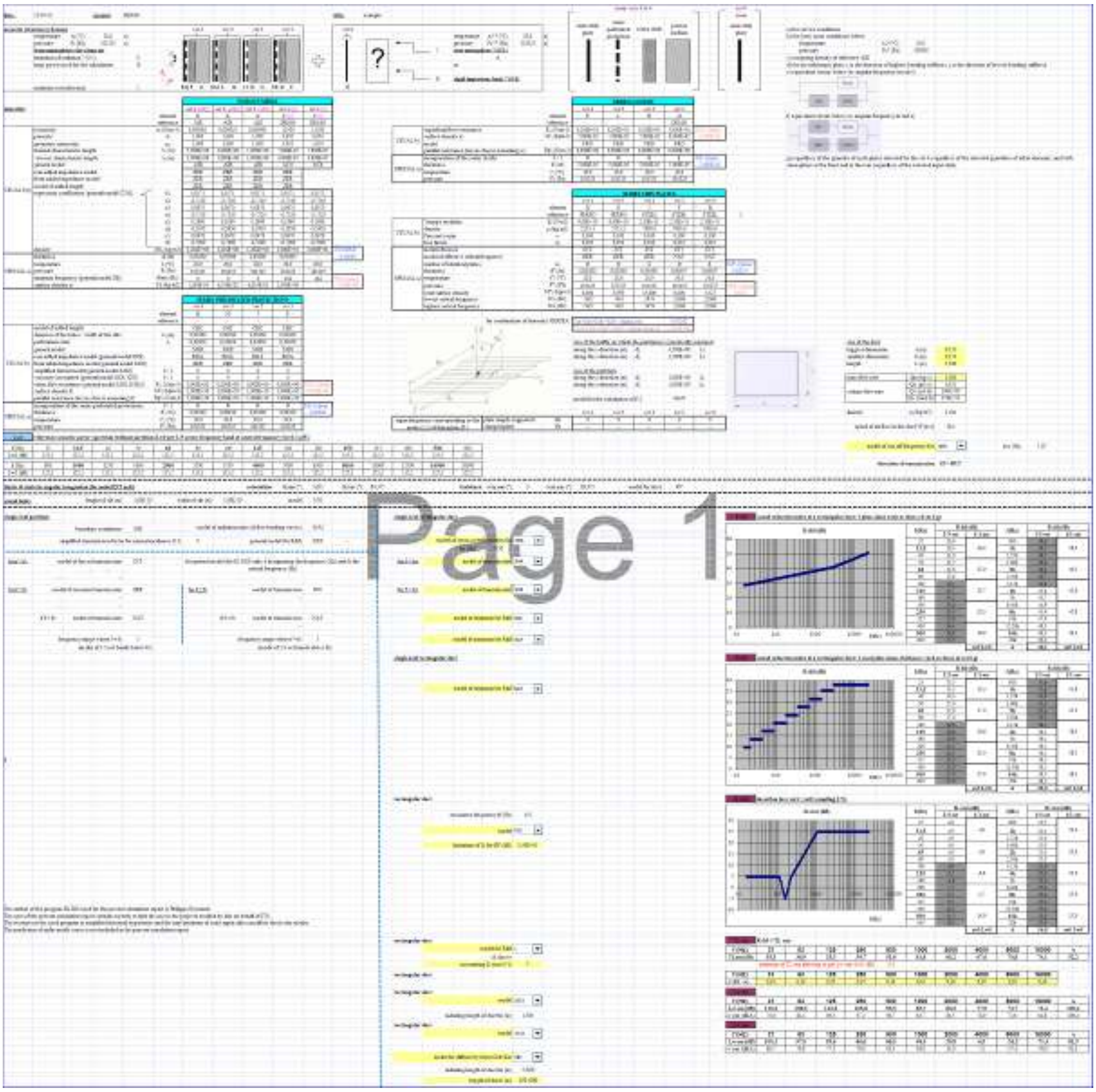
Item	Cell for input	Foreseen action	Input	See placemark
Biggest dimension a	AH49	Input a positive real	0.151	[3]
Smallest dimension b	AH50	Input a positive real	0.151	[3]
Length L	AH51	Input a positive real	-	
Mass flow rate	AH53	Input a positive real	-	
Model of cut-off frequency fco	AH60	Select a model (in the proposed list)	-	
Model of cross over frequency fcr	R81	Select a model (in the proposed list)	SMA	[5]
For f<fcr model of transmission	R85	Select a model (in the proposed list)	SMA	[5]
For f>fcr model of transmission	R90	Select a model (in the proposed list)	SMA	[5]
Model of minimum for Rdif	R95	Select a model (in the proposed list)	ZER	[5]
Model of maximum for Rdif	R99	Select a model (in the proposed list)	NAT	[5]

<u>Screenshots of the worksheets (for the example of computation)</u>

Screenshot of worksheet [in-out COALA]



Screenshot of worksheet [in-out CORED IN->OUT]



Example 3.4.2 circular duct wall (pipe)

Envisaged application

It is wished to compute the breakout transmission loss of a circular duct wall (pipe) for service conditions: temperature 100°C [1], pressure 1E6 Pa [2]. The duct is made of steel [3], for which the natural effective critical frequency is considered [4] with a thickness 10 mm [5], with a diameter D=300mm [6]. Regarding models of computation: the procedures basing the model referred to as 3733 are selected [7] with an average value for accounting mounting [8]

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA]

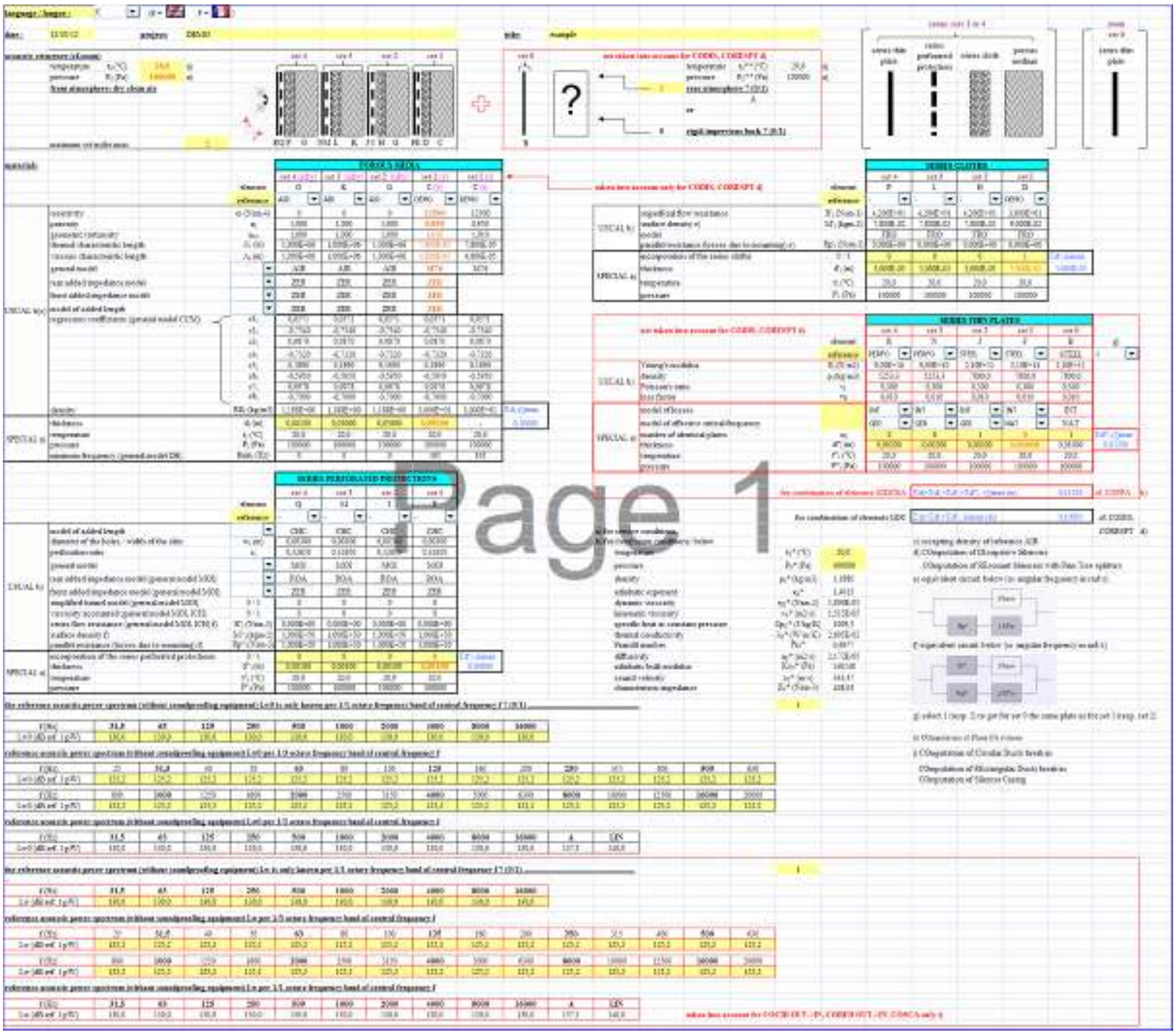
Item	Cell for input	Foreseen action	Input	See placemark / comment
Temperature	D6	Input a real number	20	[1]
Pressure	D7	Input a real positive number	100000	[2]
Reference	W31	Select a reference (material in the proposed list)	STEEL	[3]
g)	Y31	Select 1 or 2 in the proposed list	1	
Model of effective critical frequency	W37	Select a model (in the proposed list)	NAT	[4]
Thickness	W38	Input a real positive number	0.010	[5]

Worksheet [in-out COCID IN->OUT]

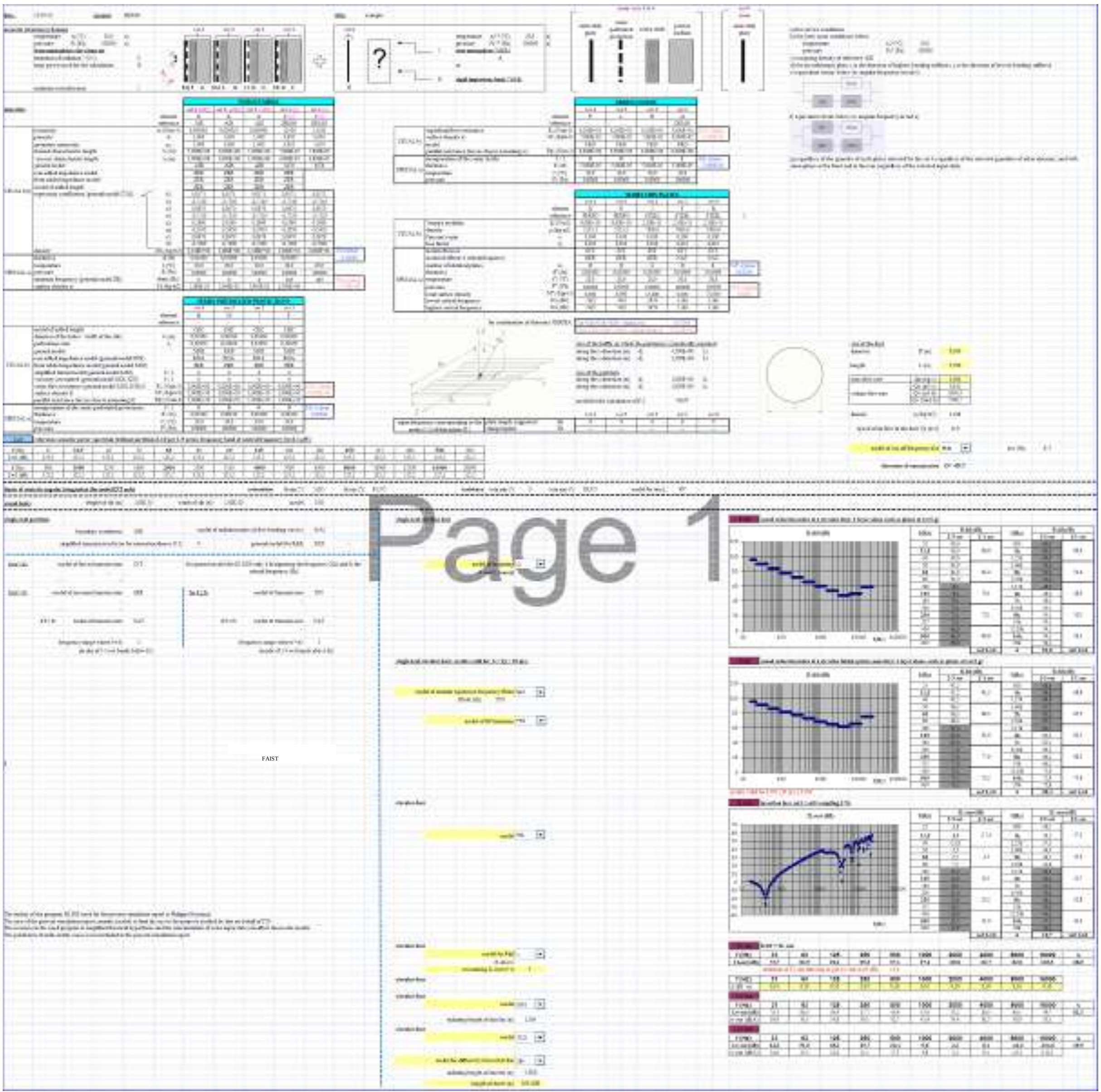
Item	Cell for input	Foreseen action	Input	See placemark
Diameter D	AH49	Input a positive real	0.3	[6]
Length L	AH51	Input a positive real	-	
Mass flow rate	AH53	Input a positive real	-	
Model of cut-off frequency fco	AH64	Select a model (in the proposed list)	-	
Model of mounting	R85	Select a model (in the proposed list)	c)	[8]

<u>Screenshots of the worksheets (for the example of computation)</u>

Screenshot of worksheet [in-out COALA]



Screenshot of worksheet [in-out COCID IN->OUT]



Example 3.4.3 circular duct wall (spiral-seam pipe)

Envisaged application

It is wished to compute the breakout transmission loss of a circular duct wall (spiral-seam pipe) for room conditions: temperature 17°C [1], pressure 1E5 Pa [2]. The duct is made of steel [3], for which the natural effective critical frequency is considered [4] with a thickness 0.65 mm [5], with a diameter D=250mm [6]. The length of the duct is 1 m [7]. The flow rate is 1400 m3/h [8]. The sound velocity in steel is accounted as 5100 m/s. Regarding models of computation: the procedures basing the model referred to as 2081 are selected [9] except for the high frequency [10].

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA]

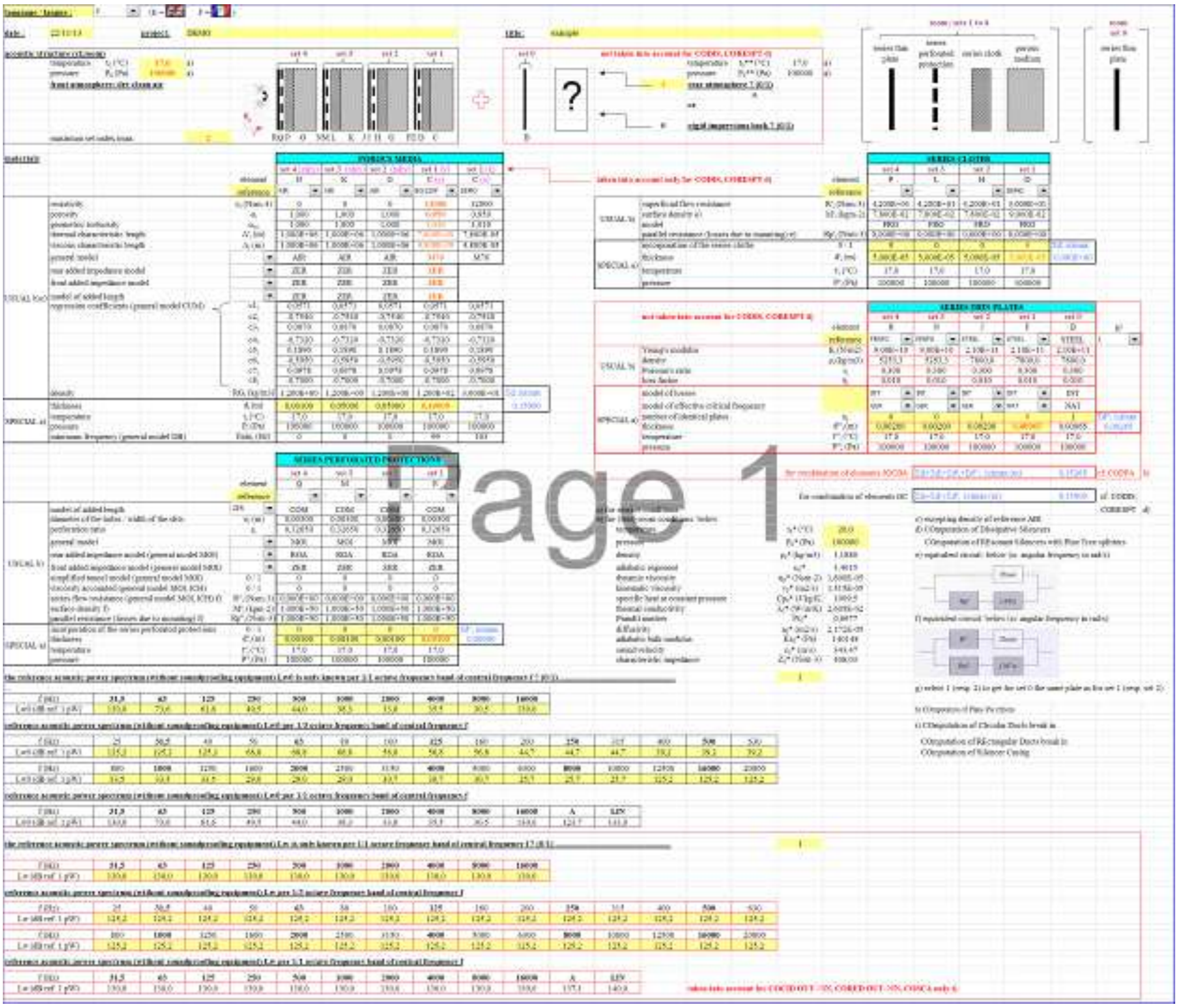
Item	Cell for input	Foreseen action	Input	See placemark / comment
Temperature	D6	Input a real number	17	[1]
Pressure	D7	Input a real positive number	100000	[2]
Reference	W31	Select a reference (material in the proposed list)	STEEL	[3]
g)	Y31	Select 1 or 2 in the proposed list	1	
Model of effective critical frequency	W37	Select a model (in the proposed list)	NAT	[4]
Thickness	W38	Input a real positive number	0.00065	[5]
Reference acoustic power spectrum	D65 to K65	Input numbers	73.6; 61.6; 49.5; 44.0; 38.3; 33.8; 35.5; 30.5	[11]

Worksheet [in-out COCID IN->OUT]

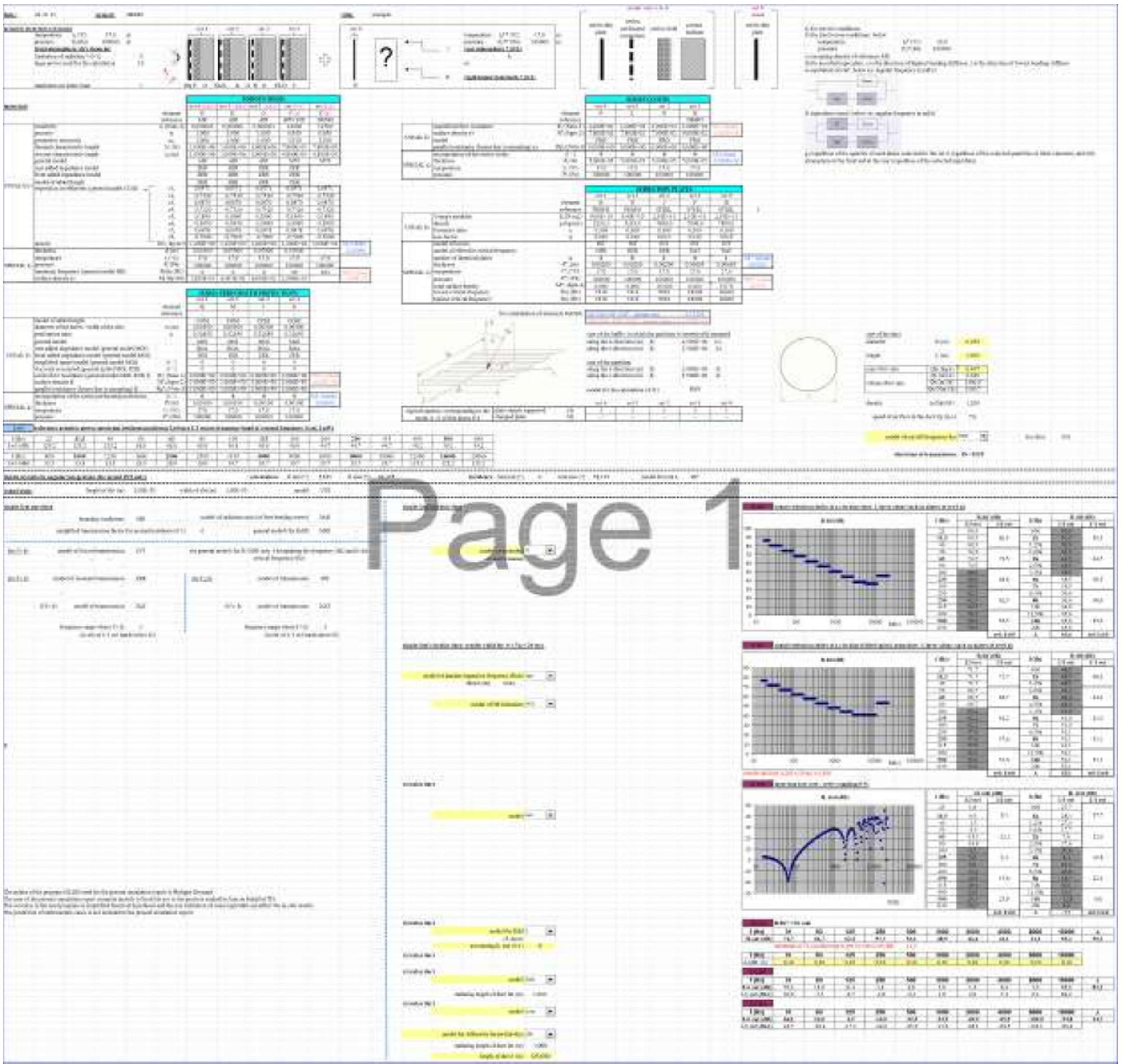
Item	Cell for input	Foreseen action	Input	See placemark
Diameter D	AH49	Input a positive real	0.25	[6]
Length L	AH51	Input a positive real	1	[7]
Mass flow rate	AH53	Input a positive real	=1400/3600*AH58	[8]
Model of cut-off frequency fco	AH64	Select a model (in the proposed list)	-	-
model of annular expansion frequency fRokt	R108	Select a model (in the proposed list)	NAT	[9]
model of HF limitation	R113	Select a model (in the proposed list)	MOI	[9]
model for Rdif	R149	Select a model (in the proposed list)	2	-

Screenshots of the worksheets (for the example of computation)

Screenshot of worksheet [in-out COALA]



Screenshot of worksheet [in-out COCID IN->OUT]



Appendix to Section 3: list of symbols

General

Cf. corresponding § in Section 1 and 2

Duct wall

a: biggest (inner) dimension of the cross section of a rectangular duct
b: smallest (inner) dimension of the cross section of a rectangular duct
D: (inner) diameter of a rectangular duct
fco: cut-off frequency of the duct (Hz)
fcr: cross over frequency (Hz)
fR: annular expansion frequency (Hz)

Miscellaneous

See also corresponding § in General considerations and in Section 1 and 2

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Section 4: computation of duct straight runs (MODULE 4 of the software)

4.1: Introduction

Terms and definitions

For the needs of the present user's manual, the following terms and definition apply:

No particular term or definition (cf. section 1, section 2, cf. section 3)

Mountings and geometry

The geometry used for the computation of duct straight runs is as follows:

cross section
rectangular
circular

4.2: Scientific and technical background

The prediction of acoustic performances of ducts straight runs with SILDIS is founded on a scientific and technical background in relation with:

- analytical models for taking into account the properties of materials and various physical phenomena useful on the occasion of the computation
- measurement results for feeding some of those models and for allowing the necessary improvement (through correction factors) of the correlation between some calculations and on site observations

The obtained results are not comparable with standardized measurement due to the lack of such documents.

4.2.1Thermodynamics and fluid dynamics:

- **Steps of the computation**

Step [a]

All computations have been gathered in this single step for the sake of simplicity. See corresponding § in Section 1

4.2.2 Acoustics:

- **Bloc diagram** on fig 4.1 below

Fig. 4.1

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRxx-015x]

Note 2: the main steps (the steps involving a physical modeling) being referred to from [AR] to [AU] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

- **Steps of the computation**

Step [AR] only for applications related to air conditioning systems made of thin duct walls (i.e. not for applications involving stacks made of thick duct walls)

This step aims at calculating the **(longitudinal) attenuation (per unit length)** of duct straight runs

- ***Bibliography (references) :***

[AR1] -	
[AR2]	
[AR3]	
[AR4]	
[AR5]	

- ***Comments :***

  - when used, the **cut off frequency** for the first higher mode **fco** is computed depending on the speed of sound **c**, the Mach number in the airways **M**, and the geometry of the duct, according to various models as shown in the table below:

model	**HAN**	MUN
source	[AR1]	[AR2]

  - when used, the model of **(longitudinal) attenuation (per unit length)** is selected among various models as shown in the table below:

✓ rectangular duct

model	**2081-R**	SMA-R	ASH 150*150	ASH 305*305	ASH 305*610
source	[AR3]	[AR4]	[AR5]	[AR5]	[AR5]
comment	thickness 1 mm, (rectangular) dimension 0.10 m up to 1.00 m	(rectangular)	for (rectangular) cross section 150 mm * 150 mm	for (rectangular) cross section 305 mm * 305 mm	for (rectangular) cross section 305 mm * 610 mm

model	ASH 610*610	ASH 1220*1220	ASH 1830*1830	ZER
source	[AR5]	[AR5]	[AR5]	
comment	For (rectangular) cross section 610 mm * 610 mm	for (rectangular) cross section 1220 mm * 1220 mm	for (rectangular) cross section 1830 mm * 1830 mm	ZERo attenuation

✓ circular duct

model	**2081-C**	ASH D≤180	ASH 180<D≤380	ASH 380<D≤760	ASH 760<D≤1520	ZER
source	[AR3]	[AR5]	[AR5]	[AR5]	[AR5]	
comment	thickness 1 mm, (rectangular) diameter 0.10 m up to 1.00 m	for circular cross section diameter D ≤ 180 mm	for circular cross section 180 mm < D ≤ 380 mm	for circular cross section 380 mm < D ≤ 760 mm	for circular cross section 760 mm < D ≤ 1520 mm	ZERo attenuation

Step [AS]

This step aims at calculating the **insertion loss without self noise** of duct straight runs

- ***Bibliography (references) :***

[AS1]	

  - ***Comments :***

    - the **insertion loss without flow noise D'i** is computed according to various models as shown in the table below:

model	3733G	3733T	COEDLA
source	[AS1]	[AS1]	step [AR]
comment	only for applications involving stacks made of thick duct walls (based on graphic displayed in [AS1])	only for applications involving stacks made of thick duct walls (based on table displayed in [AS1])	only for applications related to air conditioning systems made of thin duct walls cf. step [AR]

Step [AT]

This step aims at taking into account the **self noise of** duct straight runs **(noise produced by the airflow).**

For dissipative silencers

- ***Bibliography (references) :***

[AT1]	
[AT2]	
[AT3]	
[AT4]	
[AT5] -	

- ***Comments*:** the self noise (acoustic power of flow noise **Lw** in dB ref 1E-12W) is basically computed at frequency steps of 1/1 octave.

  - **for rectangular cross sections as well as for circular cross sections**, the determination of the self noise is done according various models as shown in the tables below:

model	**2081B**	3733A1	3733A2	3733B
source	[AT1] (**)(***)	[AT2] (**)(***)	[AT3] (**)(***)	[AT4] (**)(***)

  - for the models 2081 and 3733, a spectral correction is used according various models as shown in the tables below:

model	2081	**FRO**	3733
source	[AT4]	**[AT5]**	[AT3]

Warning: at the time of the writing of this manual, all the consequences of the choice of one or the other model are not known with accuracy. The choice of the model can be done by the user allowing tests and feed-back.

Step [AU]

This step aims at calculating the **insertion loss of the duct including its self noise**.

- ***Bibliography (references) :***

[AU1] -	

- ***Comments :***

The sound power level downstream of the straight duct including self noise (**Lw1** in dB ref 1E-12W) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

Lw1 = 10 * log [10^ (0.1 * (Lw0 – Di')) + 10^ (0.1 * Lw)]

Lw being the self noise (acoustic power of flow noise in dB ref 1E-12W)

The insertion loss taking into account the self noise (**Di** in dB) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

Di = Lw0 – Lw1

In case of rectangular ducts, the obtained results are comparable with the standardized measurement: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units- Insertion loss, flow noise and total pressure loss (2004).

4.3: How to use SILDIS

Operating conditions / security level / safety

See corresponding § in the chapter **General considerations**

For safety reasons, some cells of the original file provided to the user (as mentioned in the table below) for which input data are foreseen to be entered by the user are pre-filled with the value "1/0", among the yellow cells for which the color orange is used (*).

Worksheet	Cells
[in COALA]	E13, J37, W38

* something like that

** attention has to be paid to the fact that the considered sheet is not included in the worksheets listed below

Worksheets

Regarding the COmputation of BENDs, the software SILDIS is configurated in order to allow the user to access to various worksheets being linked as shown in fig.4.2 (the overview of the worksheets being shown in table below).

[in-out COEDLA] → **[in-out COSTDUC]**

Fig. 4.2

Note: temperature and pressure conditions as well as reference spectrum one should enter in worksheet in COALA

Worksheet	Suitable for mountings	Input data	Results
[in COALA]	all	for climatic conditions, for reference spectrum	--
[in-out COEDLA]	COmputation of Empty Ducts Longitudinal Attenuation	for duct: dimensions	indicators of performance (acoustics)
[in-out COSTDUC]	COmputation of STraigtht DUcts	for duct: dimensions, flow rate	indicators of performance (acoustics)

Input data, alerts and results: the key points

Worksheet [in-out COEDLA]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
mass flow rate Qm (kg/s)	I5	Input a real	useless input data given the development of SILDIS
model of cut-off frequency fco	P5	Select a model (in the proposed list)	useless input data given the development of SILDIS

Only in case of a rectangular cross section

Item	Cell for input	Foreseen action	Comment
biggest dimension (m)	P23	Input a real	
smallest dimension (m)	P24	Input a real	
model of attenuation	P32	Select a model (in the proposed list)	

Only in case of a circular cross section

Item	Cell for input	Foreseen action	Comment
diameter (m)	P47	Input a real	
model of attenuation	P57	Select a model (in the proposed list)	

Worksheet [in-out COSTDU]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
mass flow rate Qm (kg/s)	I5	Input a real	
model of cut-off frequency fco	N5	Select a model (in the proposed list)	
model of insertion loss	S5	Select a model (in the proposed list)	
duct length (m)	X5	Input a real	
model of self noise	AC5	Select a model (in the proposed list)	
model of spectral correction	AC10	Select a model (in the proposed list)	

Only in case of a rectangular cross section

Item	Cell for input	Foreseen action	Comment
biggest dimension (m)	P23	Input a real	
smallest dimension (m)	P24	Input a real	

Only in case of a circular cross section

Item	Cell for input	Foreseen action	Comment
diameter (m)	P47	Input a real	

- ***Main displays of the results :***

Worksheet [in-out COEDLA]

Table of results in case of rectangular cross section

- **longitudinal attenuation Δ**: see lines 21 to 24 (columns S to AC)

Tables of results in case of circular cross section

- **longitudinal attenuation Δ**: see lines 44 to 47 (columns S to AC)

Worksheet [in-out COSTDU]

Tables of results in case of rectangular cross section

- **insertion loss without self noise Di'**: see lines 21 to 24 (columns S to AD)
- **self noise Lw**: see lines 26 to 30 (columns S to AD)
- **sound power level downstream of straight duct section**: see lines 32 to 36 (columns S to AD)

- **insertion loss with self noise Di**: see lines 38 to 41 (columns S to AD)

<u>**Tables of results in case of circular cross section**</u>

- **insertion loss without self noise Di'**: see lines 44 to 47 (columns S to AD)
- **self noise Lw**: see lines 49 to 53 (columns S to AD)
- **sound power level downstream of straight duct section:** see lines 55 to 59 (columns S to AD)
- **insertion loss with self noise Di**: see lines 61 to 64 (columns S to AD)

4.4: Examples of computation with SILDIS

<u>Example 4.4.1</u> rectangular straight duct (air conditioning system)

<u>*Envisaged application*</u>

It is wished to compute the sound power level downstream of a rectangular straight duct for room conditions: temperature 17°C [1], pressure 1E5 Pa [2]. The duct is made of steel [3], with a thickness 1 mm [4], with a width B=0.5 m [5], and with a height H= 0.4 m [6]. The length of the duct is 4 m [7]. The flow rate is 4200 m3/h [8]. Regarding models of computation: the procedures basing the model referred to as 2081 are selected [9].

Note: the sound power spectrum upstream of the considered straight duct section is as shown in the table below [10].

F(Hz)	63	125	250	500	1000	2000	4000	8000
Lw0 (dB ref 1pW)	80.8	68.3	48.9	44.9	40.2	39.5	44.0	39.1

<u>*Input data*</u>

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA]

Item	Cell for input	Foreseen action	Input	See placemark / comment
Temperature	D6	Input a real number	17	[1]
Pressure	D7	Input a real positive number	100000	[2]
Reference acoustic power spectrum	D65 to K65	Input numbers	80.8 ; 68.3 ; 48.9 ; 44.9 ; 40.2 ; 39.5 ; 44.0 ; 39.1	[10]

Worksheet [in-out COEDLA]

Item	Cell for input	Foreseen action	Input	See placemark / comment
mass flow rate Qm (kg/s)	I5	Input a real	-	
model of cut-off frequency fco	P5	Select a model (in the proposed list)	-	

Only in case of a rectangular cross section

Item	Cell for input	Foreseen action	Input	See placemark / comment
biggest dimension (m)	P23	Input a real	0.5	[5]
smallest dimension (m)	P24	Input a real	0.4	[6]
model of attenuation	P32	Select a model (in the proposed list)	2081-R	[9]

Worksheet [in-out COSTDU]

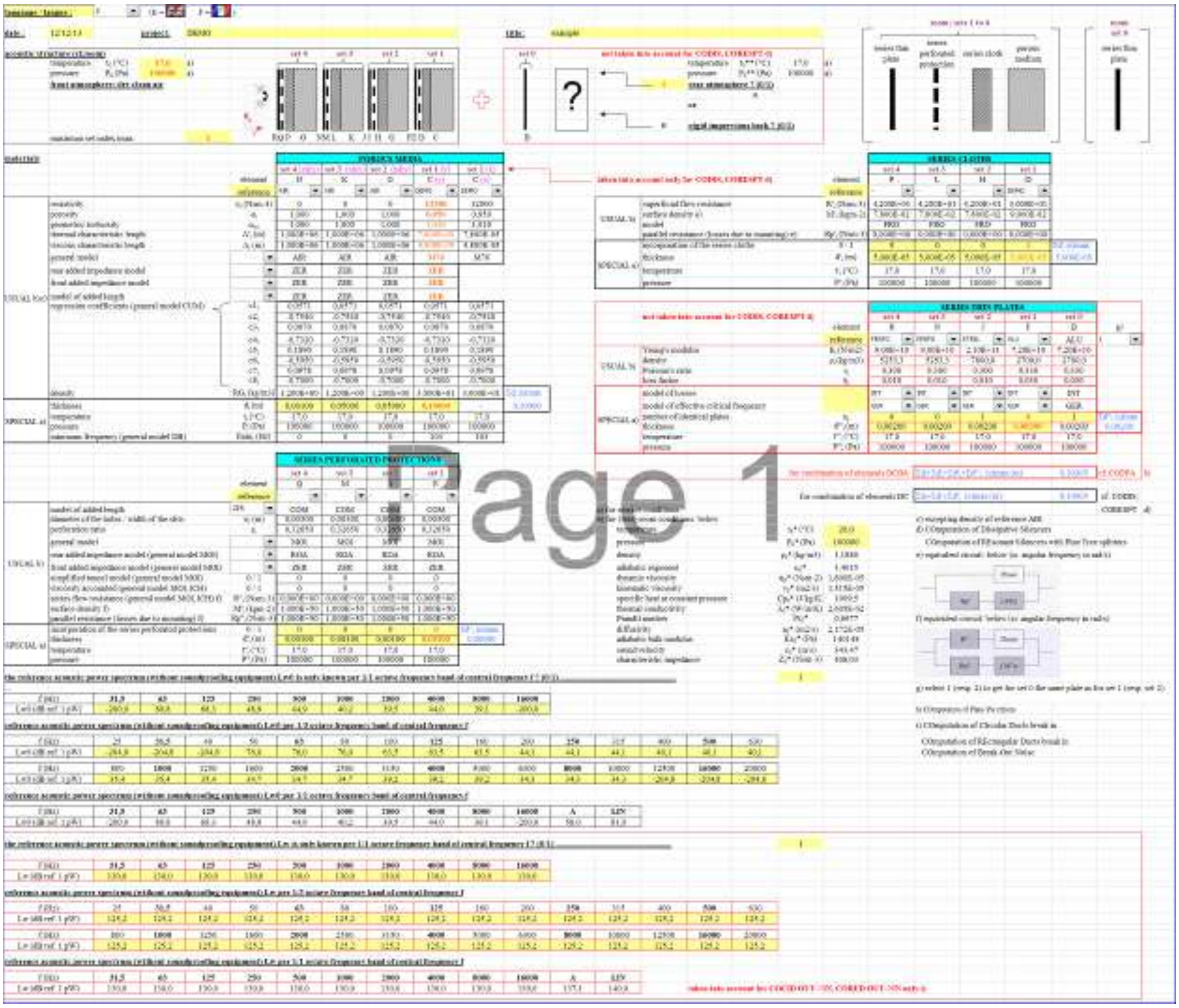
Item	Cell for input	Foreseen action	Input	See placemark / comment
mass flow rate Qm (kg/s)	I5	Input a real	=4200/3600*I10	[8]
model of cut-off frequency fco	N5	Select a model (in the proposed list)	HAN	
model of insertion loss	S5	Select a model (in the proposed list)	COEDLA	
duct length (m)	X5	Input a real	4	[7]
model of self noise	AC5	Select a model (in the proposed list)	2081B	[9]
model of spectral correction	AC10	Select a model (in the proposed list)	2081	[9]

Only in case of a rectangular cross section

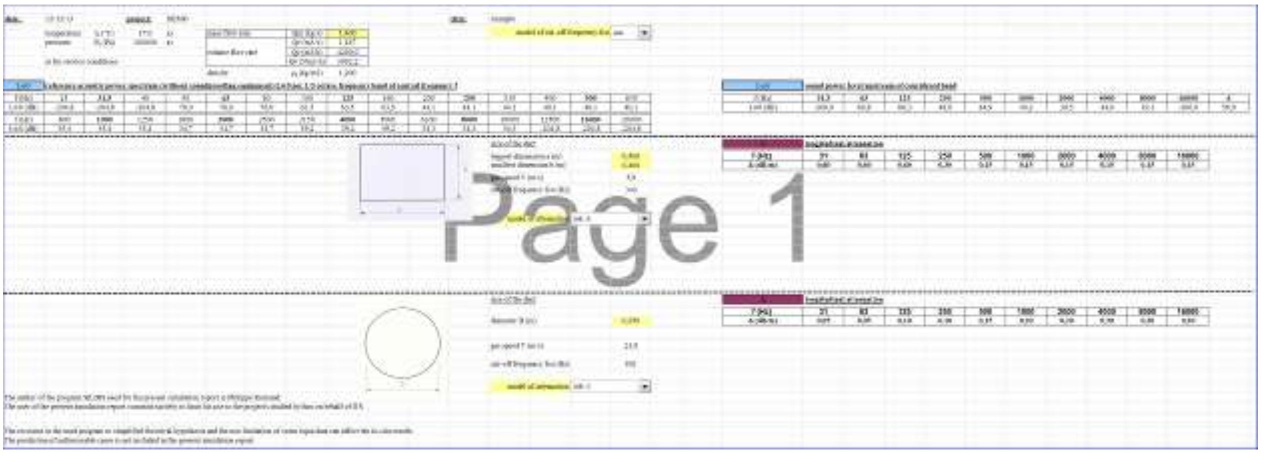
Item	Cell for input	Foreseen action	Input	See placemark / comment
biggest dimension (m)	P23	Input a real	0.5	[5]
smallest dimension (m)	P24	Input a real	0.4	[6]

<u>Screenshots of the worksheets (for the example of computation)</u>

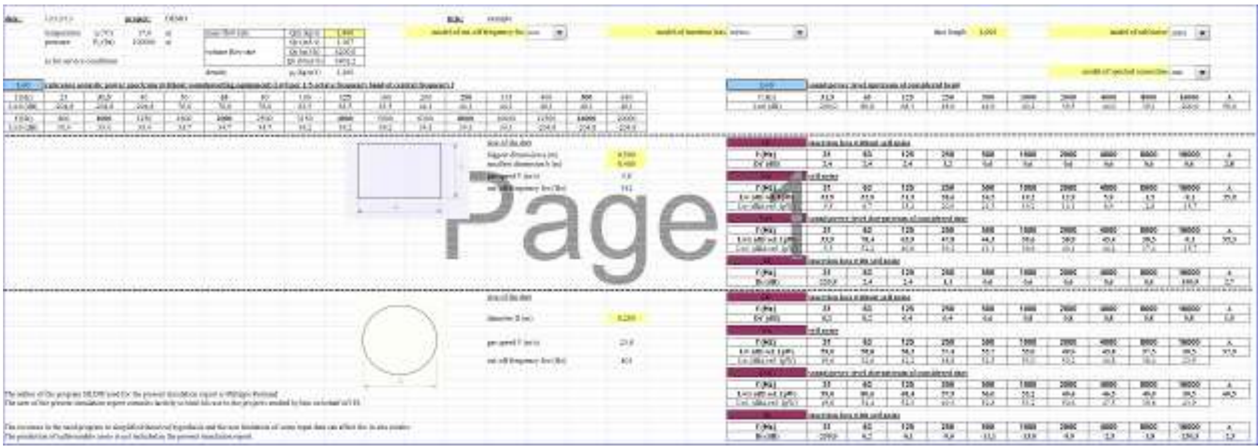
Screenshot of worksheet [in-out COALA]



Screenshot of worksheet [in-out COEDLA]



Screenshot of worksheet [in-out COSTDU]



Example 4.4.2 circular straight duct (air conditioning system)

Envisaged application

It is wished to compute the sound power level downstream of a circular straight duct for room conditions: temperature 17°C [1], pressure 1E5 Pa [2]. The duct is made of steel [3], with a thickness 1 mm [4], with a diameter D=0.25 m [5]. The length of the duct is 7 m [6]. The flow rate is1400 m3/h [7]. Regarding models of computation: the procedures basing the model referred to as 2081 are selected [8].

Note: the sound power spectrum upstream of the considered straight duct section is as shown in the table below [9].

F(Hz)	63	125	250	500	1000	2000	4000	8000
Lw0 (dB ref 1pW)	73.6	61.3	45.7	42.1	38.4	36.1	38.8	33.9

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA]

Item	Cell for input	Foreseen action	Input	See placemark / comment
Temperature	D6	Input a real number	17	[1]
Pressure	D7	Input a real positive number	100000	[2]
Reference acoustic power spectrum	D65 to K65	Input numbers	73.6 ; 61.3 ; 45.7 ; 42.1 ; 38.4 ; 36.1 ; 38.8 ; 33.9	[9]

Worksheet [in-out COEDLA]

Item	Cell for input	Foreseen action	Input	See placemark / comment
mass flow rate Qm (kg/s)	I5	Input a real	-	
model of cut-off frequency fco	P5	Select a model (in the proposed list)	-	

Only in case of a circular cross section

Item	Cell for input	Foreseen action	Input	See placemark / comment
diameter (m)	P47	Input a real	0.250	[5]
model of attenuation	P57	Select a model (in the proposed list)	2081-C	[8]

Worksheet [in-out COSTDU]

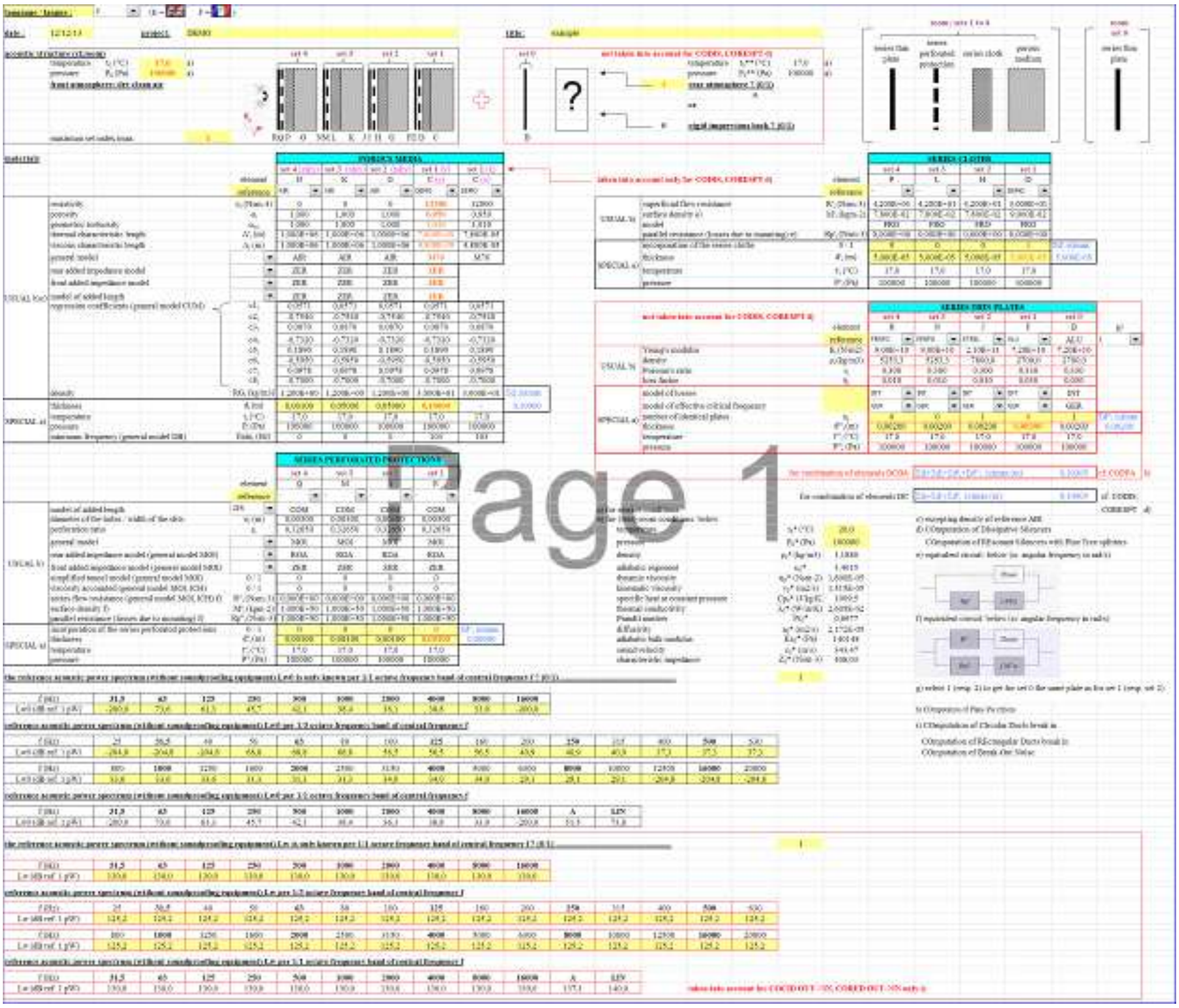
Item	Cell for input	Foreseen action	Input	See placemark / comment
mass flow rate Qm (kg/s)	I5	Input a real	=1400/3600*I10	[7]
model of cut-off frequency fco	N5	Select a model (in the proposed list)	HAN	
model of insertion loss	S5	Select a model (in the proposed list)	COEDLA	
duct length (m)	X5	Input a real	7	[6]
model of self noise	AC5	Select a model (in the proposed list)	2081B	[8]
model of spectral correction	AC10	Select a model (in the proposed list)	2081	[8]

Only in case of a circular cross section

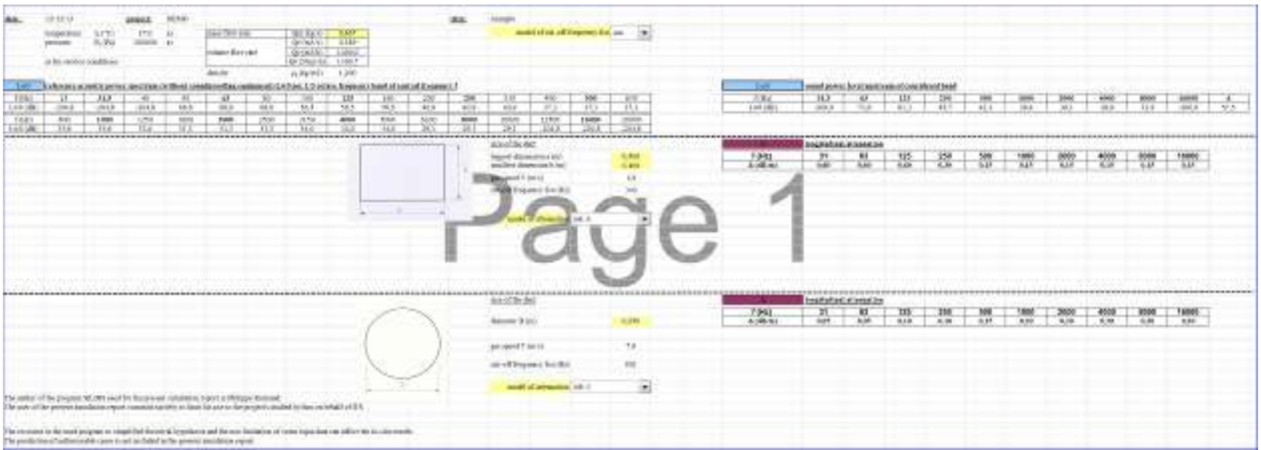
Item	Cell for input	Foreseen action	Input	See placemark / comment
diameter (m)	P47	Input a real	0.250	[5]

Screenshots of the worksheets (for the example of computation)

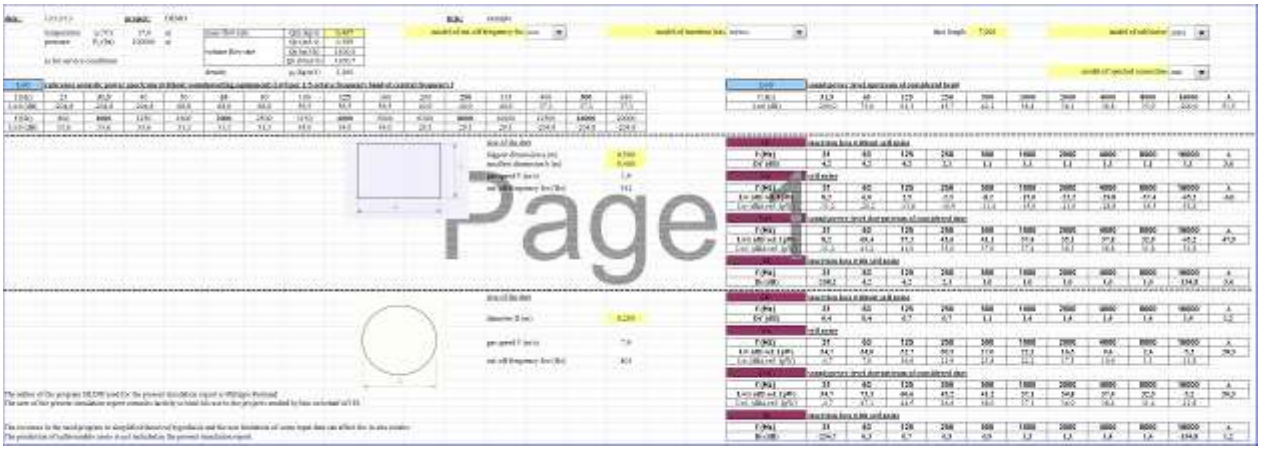
Screenshot of worksheet [in-out COALA]



Screenshot of worksheet [in-out COEDLA]



Screenshot of worksheet [in-out COSTDU]



<u>Example 4.4.3 </u>circular straight duct (exhaust stack)

<u>Envisaged application</u>

It is wished to compute the sound power level at the mouth of a circular stack for service conditions: temperature 109.85°C [1], pressure 1E5 Pa [2]. The duct is with a diameter D=6 m [3]. The height of the stack is 135 m [4]. The flow rate is 384.615 kg/s [5]. Regarding models of computation: the procedures basing the model referred to as 3733G are selected [6].

<u>Input data</u>

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA]

Item	Cell for input	Foreseen action	Input	See placemark / comment
Temperature	D6	Input a real number	109.85	[1]
Pressure	D7	Input a real positive number	100000	[2]

Worksheet [in-out COSTDU]

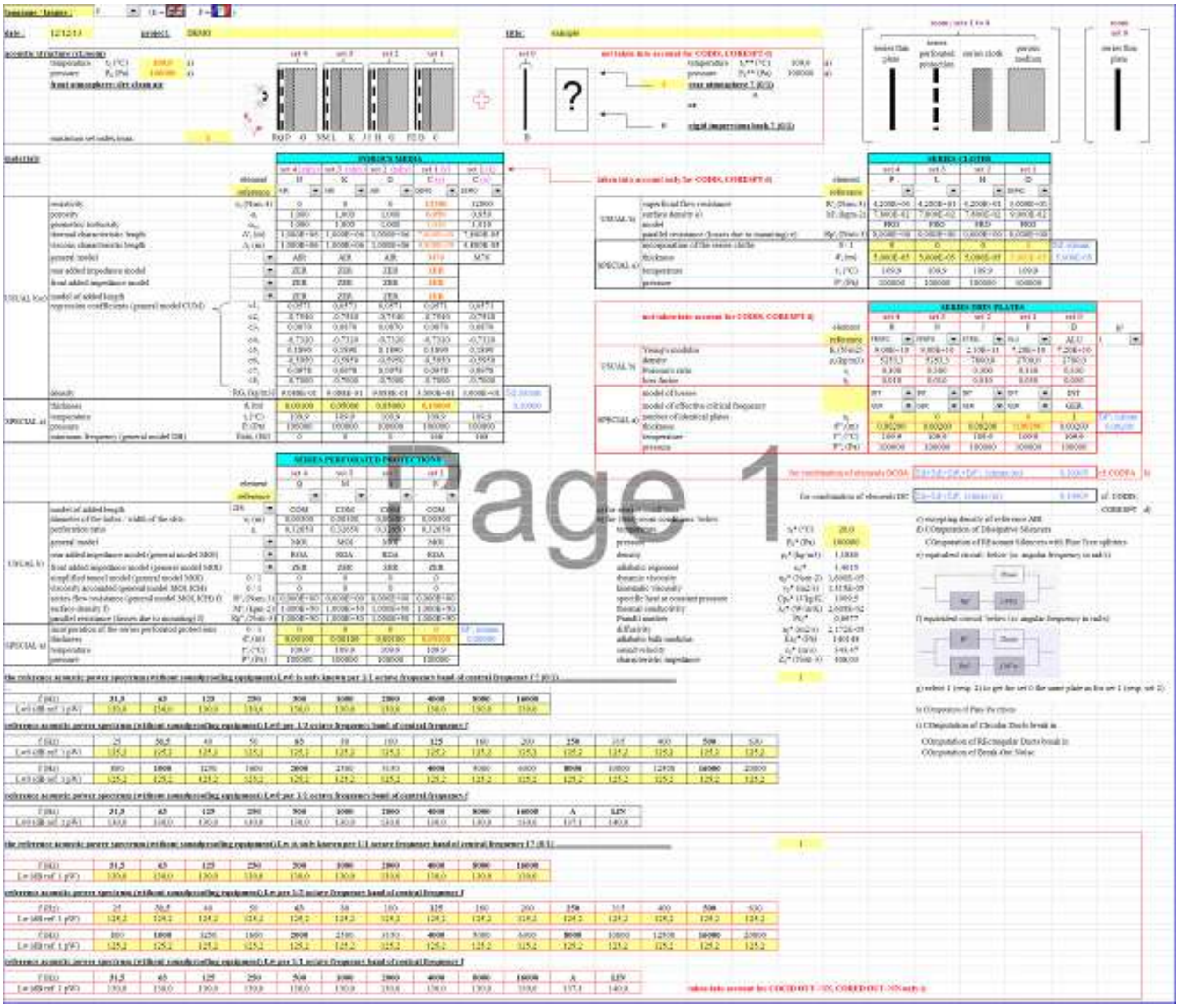
Item	Cell for input	Foreseen action	Input	See placemark / comment
mass flow rate Qm (kg/s)	I5	Input a real	384.615	[5]
model of cut-off frequency fco	N5	Select a model (in the proposed list)	-	
model of insertion loss	S5	Select a model (in the proposed list)	3733G	[5]
duct length (m)	X5	Input a real	135	[6]
model of self noise	AC5	Select a model (in the proposed list)	-	-
model of spectral correction	AC10	Select a model (in the proposed list)	-	-

Only in case of a circular cross section

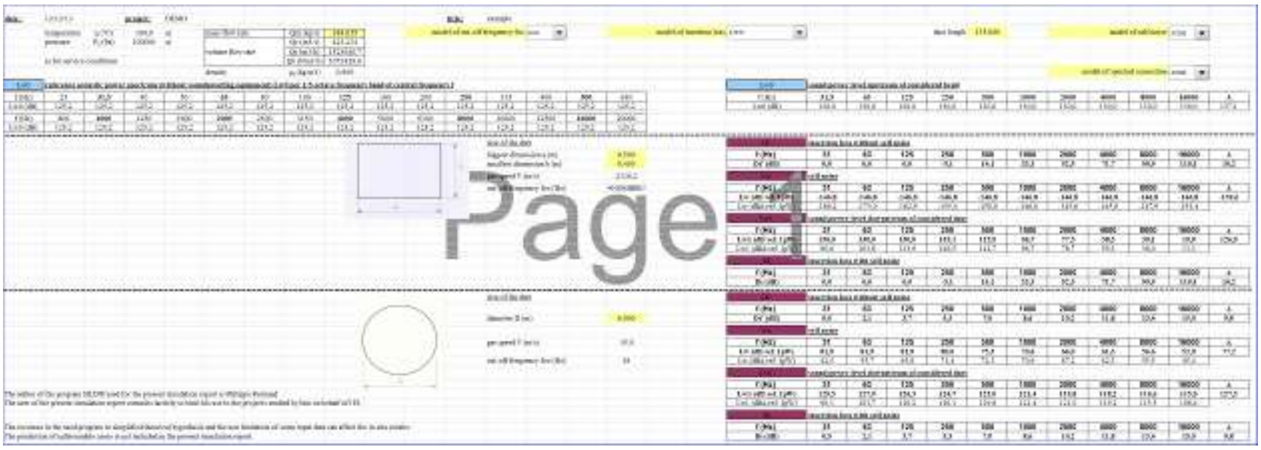
Item	Cell for input	Foreseen action	Input	See placemark / comment
diameter (m)	P47	Input a real	6	[3]

Screenshots of the worksheets (for the example of computation)

Screenshot of worksheet [in-out COALA]



Screenshot of worksheet [in-out COSTDU]



Appendix to Section 4: list of symbols

General

Cf. corresponding § in Section 1,2 and 3

Straight duct

Lw0: sound power level without soundproofing equipment (dB ref. 1pW) i.e. in the entrance plane of the duct (casing) section of interest
Lw1: sound power level with soundproofing equipment (dB ref. 1pW) i.e. in the exit plane of the duct (casing) section of interest

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Section 5: computation of break-out noise (MODULE 5 of the software)

5.1: Introduction

Terms and definitions

For the needs of the present user's manual, the following terms and definition apply:

No particular term or definition (cf. section 1, section 2, cf. section 3, cf. section 4)

Mountings and geometry

The geometry used for the design of silencer casings with the program SILDIS is as shown in section 1, section 2, cf. section 3

5.2: Scientific and technical background

The prediction of acoustic performances of ducts with SILDIS is founded on a scientific and technical background in relation with:

- analytical models for taking into account the properties of materials and various physical phenomena useful on the occasion of the computation
- measurement results for feeding some of those models and for allowing the necessary improvement (through correction factors) of the correlation between some calculations and on site observations

The obtained results are not comparable with standardized measurement due to the lack of such documents.

5.2.1Thermodynamics and fluid dynamics:

- **Steps of the computation**

Step [a]

All computations have been gathered in this single step for the sake of simplicity. See corresponding § in Section 1

5.2.2 Acoustics:

- **Bloc diagram in case of a silencer** on fig 5.1.1 below

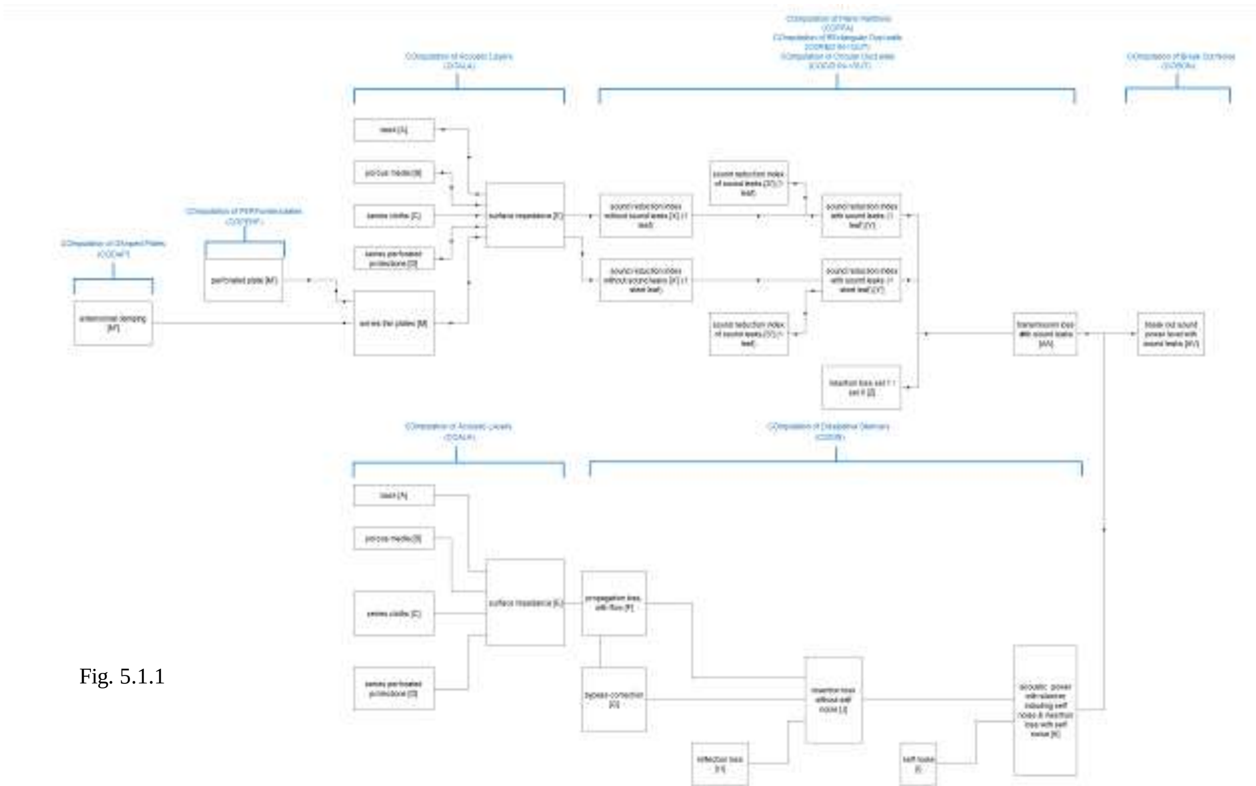


Fig. 5.1.1

- **Bloc diagram in case of an empty duct** on fig 5.1.2 below

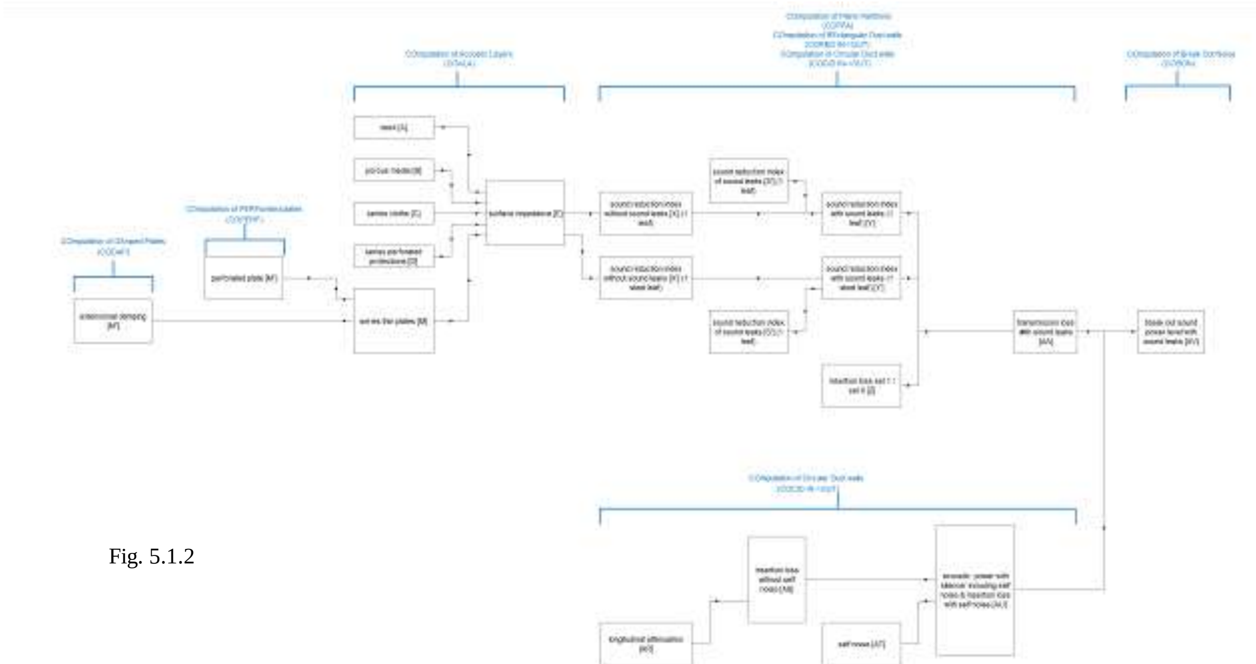


Fig. 5.1.2

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRxx-015x]

Note 2: the main steps (the steps involving a physical modeling) being referred to as [AV] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

- **Steps of the computation**

Step [AV]

This step aims at calculating the **sound power level radiated by duct (or casing) walls** with atmosphere at the front and at the rear regardless of the selected input data

- ***Bibliography (references) :***

[AV1]	
[AV2]	
[AV3] -	
[AV4]	

Comments :

- when used, the **duct (or casing) walls sound transmission loss** referred to as TL out is selected according to various models as shown in the table below:

model	COPPA	COPPA1	COPPA2	CORED	COCID	BYO
source	as derived & displayed in worksheet COPPA	as derived & displayed in worksheet COPPA1	as derived & displayed in worksheet COPPA2	as derived & displayed in worksheet CORED IN->OUT	as derived & displayed in worksheet COCID IN->OUT	TL out figures to be entered by user (BYO = Bring Your Own)

- when used, the model of silencer (i.e. the model of **silencer insertion loss** referred to as Di) is selected according to various models as shown in the table below:

model	CODIS1	CODIS2	CORESPTR	CORESPTL	ZER	BYO
source	as derived & displayed in worksheet CODIS1	as derived & displayed in worksheet CODIS1	as derived & displayed in worksheet CORESPTR	as derived & displayed in worksheet CORESPTL	insertion loss = ZERo (i.e. ZERo silencer effect)	TL out figures to be entered by user (BYO = Bring Your Own)

- the model for the **sound power level radiated by duct (or casing) walls** referred to as Lw out is selected as shown in the table below:

model	2081	HAN	ASH
source	[AV1] [AV2]	[AV3]	[AV4] (*)

*the correction factor to account for gradually decreasing values of the sound power level inside the duct as the distance from the sound source increases only accounts the sound attenuation Δ (dB/m) due to internal ductwork losses which is computed as Di/L

5.3: How to use SILDIS

Operating conditions / security level / safety

See corresponding § in the chapter **General considerations**

For safety reasons, some cells of the original file provided to the user (as mentioned in the table below) for which input data are foreseen to be entered by the user are pre-filled with the value "1/0", among the yellow cells for which the color orange is used (*).

Worksheet	Cells
[in COALA]	E13, J37, W38
[in CODAP]	W23
[in-out COPPA]	X53, X54 (**)

* something like that

** attention has to be paid to the fact that the considered sheet is not included in the worksheets listed below

Worksheets

Regarding the COmputation of Break-Out Noise, the software SILDIS is configurated in order to allow the user to access to various worksheets being linked as shown in fig. 5.21 (the overview of the worksheets being shown in table below).

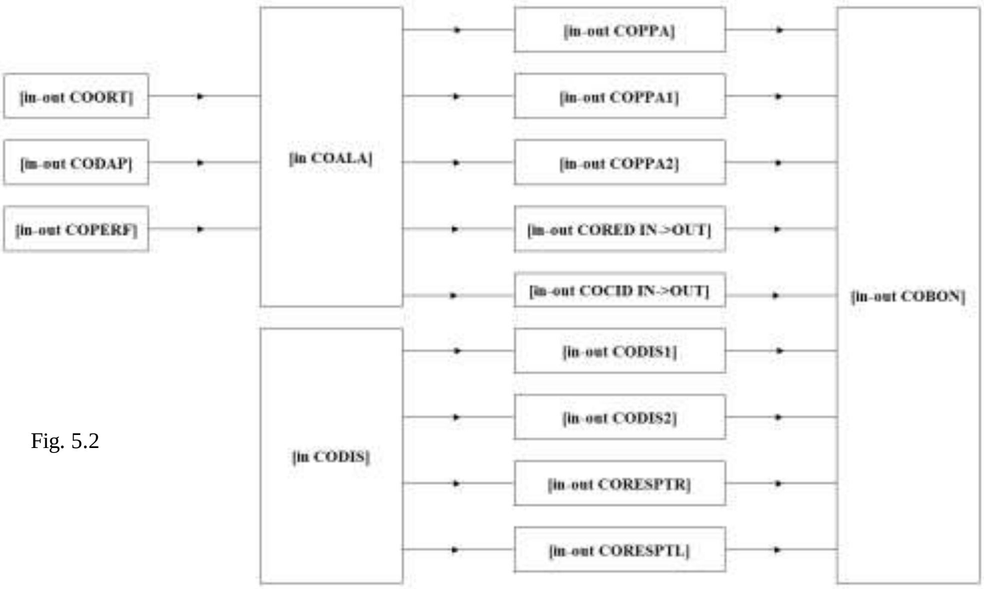


Fig. 5.2

Worksheet	Suitable for mountings	Input data	Results
[in-out CORED IN->OUT]	Rectangular duct	for duct: dimensions (for some models: longitudinal sound attenuation as well)	indicators of performance (acoustics)
[in-out COCID IN->OUT	Circular duct	for duct: dimensions (for some models: longitudinal sound attenuation as well)	indicators of performance (acoustics)
[in-out COBON]	Rectangular duct or silencer casing Circular duct or silencer casing	for duct or silencer casing: dimensions (for some models: longitudinal sound attenuation as well)	indicators of performance (acoustics)

Input data, alerts and results: the key points

The best use of the software requires the knowledge of some key points in relation with:

- the **input data**

  See corresponding § in the chapter **General considerations**
- some **alerts** in case of input data involving a warning of the user
- the place where (and the way) some **results** are presented

Those key points are reviewed worksheet per worksheet hereafter: the cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out COBON]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Perimeter of the cross section of the silencer (m)	R20	Input a positive real	
Area of the cross section of the silencer (m2)	R22	Input a positive real	
Model for TL out	R27	Select a model (in the proposed list)	
Model of silencer	R33	Select a model (in the proposed list)	
Model for Lw out	R38	Select a model (in the proposed list)	
Finite elements method (0/1) ?	R40	Input 0 to answer “no”; input 1 to answer “yes”	The recourse to finite elements method makes sense in case of ducts with a big length or in case of silencers

- ***Main displays of the results :***

Tables of results

- **sound power level radiated out of the duct (casing) section of interest**: see lines 42 to 46 (columns AA to AN)
- **sound power level downstream of considered section of duct (silencer) + sound power level radiated out of the duct (casing) section of interest**: see lines 48 to 52 (columns AA to AN)

Note:

Tables of results already displayed in other worksheets, being input data for the present worksheet

- ***sound power level in the exit plane of the duct (casing) section of interest****: see lines 18 to 22 (columns AA to AN)*
- ***sound transmission loss of the duct wall (casing)****: see lines 25 to 29 (columns AA to AN)*
- ***insertion loss of the silencer****: see lines 31 to 34 (columns AA to AN)*
- ***(longitudinal) sound attenuation****: see lines 36 to 39 (columns AA to AN)*

5.4: Examples of computation with SILDIS

Example 5.4.1 circular duct wall (spiral-seam pipe)

Envisaged application

It is wished to compute the sound power level radiated out of a circular duct walls (spiral-seam pipe) for room conditions: temperature 17°C [1], pressure 1E5 Pa [2]. The duct is made of steel [3], for which the natural effective critical frequency is considered [4] with a thickness 0.65 mm [5], with a diameter D=250mm [6]. The length of the duct is 1 m [7]. The flow rate is 1400 m3/h [8]. The sound velocity in steel is accounted as 5100 m/s. Regarding models of computation: the procedures basing the model referred to as 2081 are selected [9] except for the high frequency [10].

Note: the unsilenced sound power spectrum is as shown in the table below [11].

F(Hz)	63	125	250	500	1000	2000	4000	8000
Lw0 (dB ref 1pW)	73.6	61.6	49.5	44.0	38.3	33.8	35.5	30.5

Note: the sound power level radiated out of a circular duct walls is displayed in 2 worksheets of SILDIS: in worksheet [in-out COCID IN->OUT] and in worksheet [in-out COBON]

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).

The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA]

Item	Cell for input	Foreseen action	Input	See placemark / comment
Temperature	D6	Input a real number	17	[1]
Pressure	D7	Input a real positive number	100000	[2]
Reference	W31	Select a reference (material in the proposed list)	STEEL	[3]
g)	Y31	Select 1 or 2 in the proposed list	1	
Model of effective critical frequency	W37	Select a model (in the proposed list)	NAT	[4]
Thickness	W38	Input a real positive number	0.00065	[5]
Reference acoustic power spectrum	D65 to K65	Input numbers	73.6; 61.6; 49.5; 44.0; 38.3; 33.8; 35.5; 30.5	[11]

Worksheet [in-out COCID IN->OUT]

Item	Cell for input	Foreseen action	Input	See placemark
Diameter D	AH49	Input a positive real	0.25	[6]
Length L	AH51	Input a positive real	1	[7]
Mass flow rate	AH53	Input a positive real	=1400/3600*AH58	[8]
Model of cut-off frequency fco	AH64	Select a model (in the proposed list)	-	-
model of annular expansion frequency fRokt	R108	Select a model (in the proposed list)	NAT	[9]
model of HF limitation	R113	Select a model (in the proposed list)	MOI	[9]
model for Rdif	R149	Select a model (in the proposed list)	2	-

Only if one wishes to use the sound power level transmitted by the walls of a circular duct wall is displayed in worksheet [in-out COCID IN->OUT]

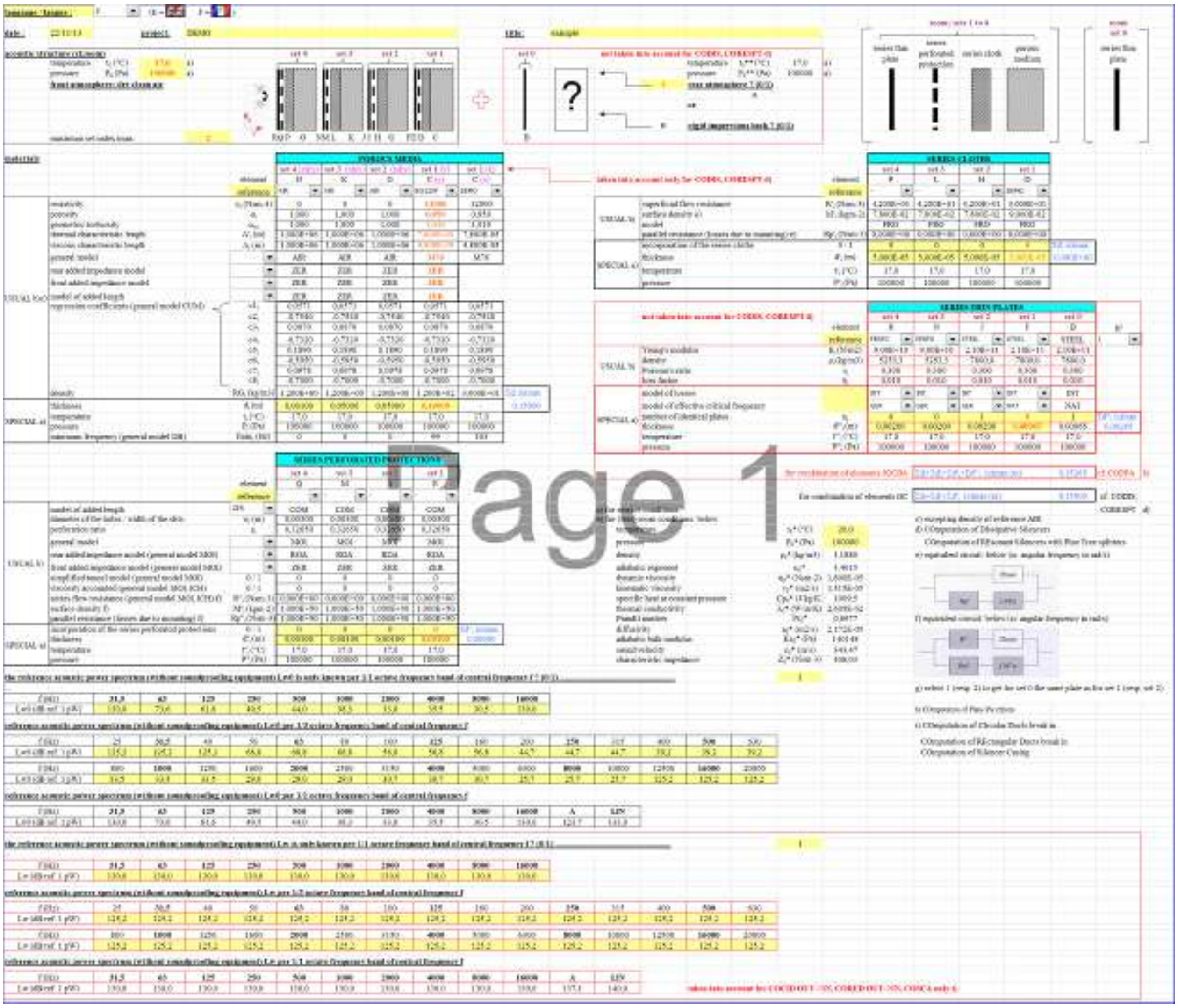
Item	Cell for input	Foreseen action	Input	See placemark
model	R158	Select a model (in the proposed list)		[9]

Worksheet [in-out COBON]

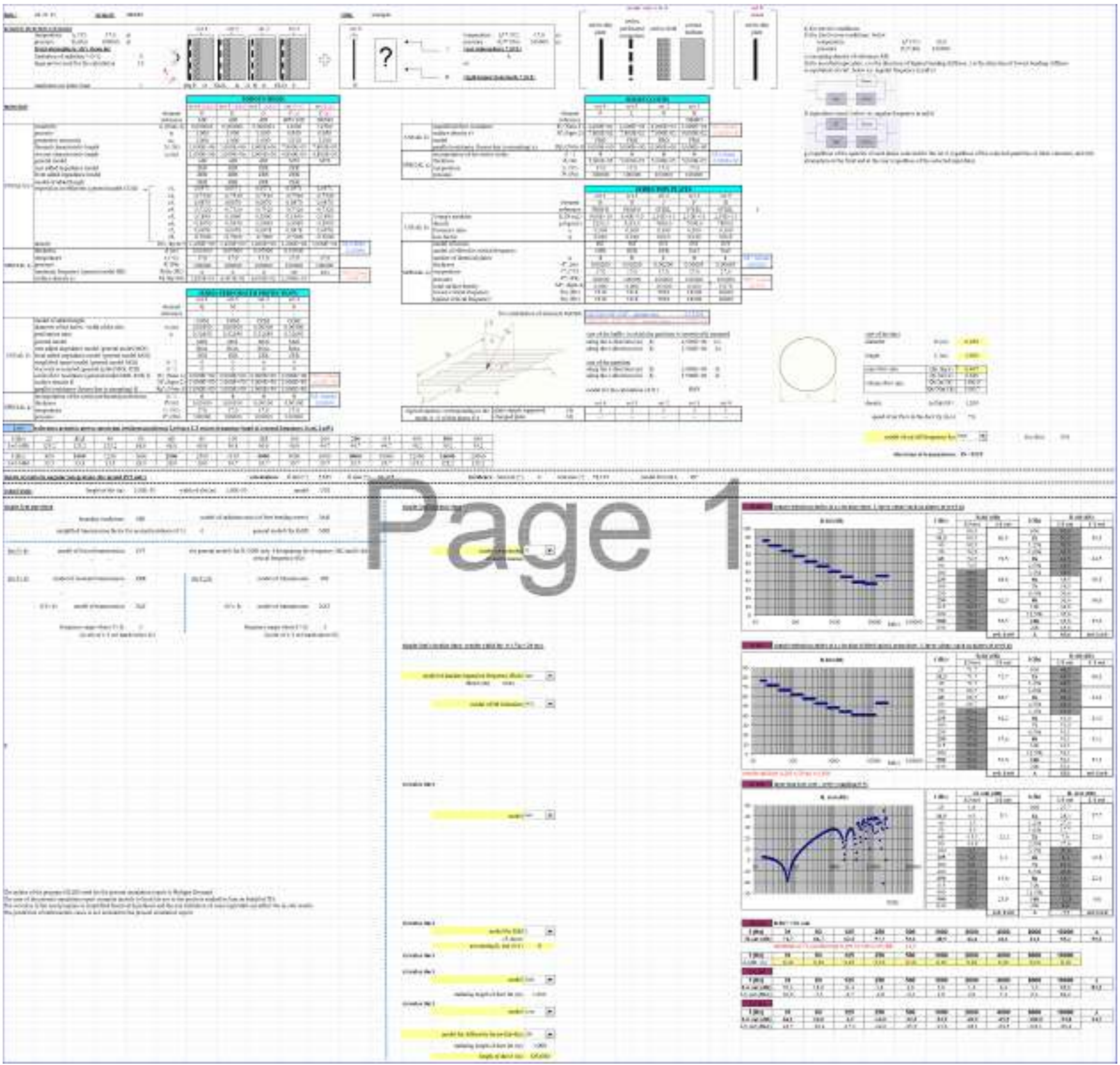
Item	Cell for input	Foreseen action	Input	See placemark
Perimeter of the cross section of the silencer (m)	R20	Input a positive real	0.7853	[6]
Area of the cross section of the silencer (m2)	R22	Input a positive real	0.049	[6]
Model for TL out	R27	Select a model (in the proposed list)	COCID	
Model of silencer	R33	Select a model (in the proposed list)	ZER	No silencing effect accounted
Model for Lw out	R38	Select a model (in the proposed list)	2081	[9]
Finite elements method (0/1) ?	R40	Input 0 to answer "no"; input 1 to answer "yes"	0	

Screenshots of the worksheets (for the example of computation)

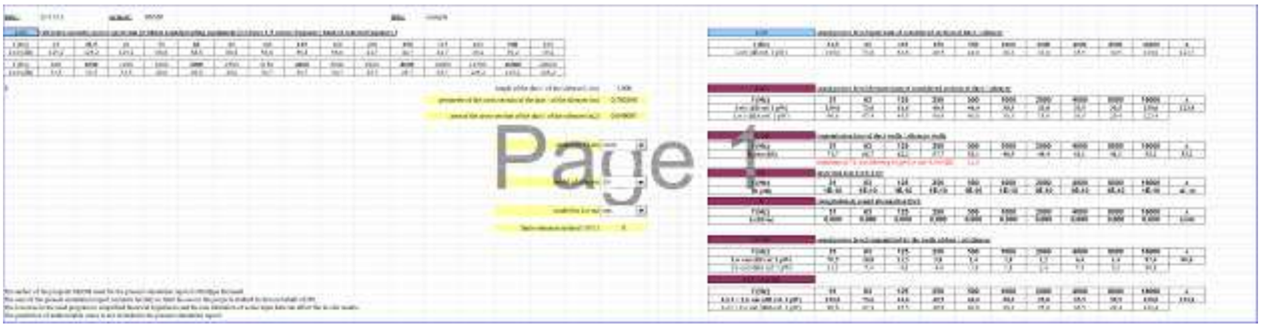
Screenshot of worksheet [in-out COALA]



Screenshot of worksheet [in-out COCID IN->OUT]



Screenshot of worksheet [in-out COBON]



Appendix to Section 5: list of symbols

General

Cf. corresponding § in Section 1,2,3 and 4

Lw0: sound power level without soundproofing equipment (dB ref. 1pW) i.e. in the entrance plane of the duct (casing) section of interest
Lw1: sound power level with soundproofing equipment (dB ref. 1pW) i.e. in the exit plane of the duct (casing) section of interest

Casing

TL out: sound transmission loss of the duct wall (casing) (dB)
Lw out: sound power level radiated by duct (casing) walls (dB ref. 1pW)

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Section 6: computation of bends (MODULE 6 of the software)

6.1: Introduction

Terms and definitions

For the needs of the present user's manual, the following terms and definition apply:

No particular term or definition (cf. section 1, section 2, cf. section 3, cf. section 4, cf. section 5, cf. section 6)

Mountings and geometry

The geometry used for the computation of bends is as follows:

inlet cross section	outlet cross section
rectangular	rectangular
circular	circular
rectangular	circular

6.2: Scientific and technical background

The prediction of acoustic performances of bends with SILDIS is founded on a scientific and technical background in relation with:

- analytical models for taking into account the properties of materials and various physical phenomena useful on the occasion of the computation
- measurement results for feeding some of those models and for allowing the necessary improvement (through correction factors) of the correlation between some calculations and on site observations

The obtained results are not comparable with standardized measurement due to the lack of such documents.

6.2.1Thermodynamics and fluid dynamics:

- **Steps of the computation**

Step [a]

All computations have been gathered in this single step for the sake of simplicity. See corresponding § in Section 1

6.2.2 Acoustics:

- **Bloc diagram** on fig 6.1 below

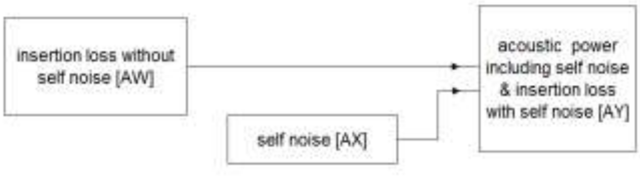


Fig. 6.1

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRxx-015x]

Note 2: the main steps (the steps involving a physical modeling) being referred to from [AW] to [AY] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

- **Steps of the computation**

Step [AW]

This step aims at calculating the **insertion loss without self noise** of bends

- ***Bibliography (references) :***

[AW1] -	
[AW2]	
[AW3]	
[AW4]	

  - ***Comments :***
    - when used, the **cut off frequency** for the first higher mode **fco** is computed depending on the speed of sound **c**, the Mach number in the airways **M**, and the geometry of the duct, according to various models as shown in the table below:

model	**HAN**	MUN
source	[AW1]	[AW2]

    - when used, the model of **90° bend (type)** is selected among various models as shown in the table below:

model	**SH-ED**	**SH-ED+TV**	**BE-RA**
source	[AW3]	[AW3]	[AW3]
comment	**SH**arp-**ED**ged	**SH**arp-**Ed**ged with**T**urning **V**anes	with **BE**nd-**RA**dius

Step [AX]

This step aims at calculating the **self noise** of bends

- ***Bibliography (references) :***

[AX1] -	
[AX2]	
[AX3]	
[AX4]	

  - ***Comments :***
    - the **self noise** is computed according to various models as shown in the table below:

model	HAN	2081	SMA
source	[AX1]	[AX3]	[AX4]

Step [AY]

This step aims at calculating the **insertion loss of the bend including its self noise**.

  - ***Bibliography (references) :***

[AY1] -	

- ***Comments :***

  The sound power level downstream of the bend including self noise (**Lw1** in dB ref 1E-12W) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

  Lw1 = 10 * log [10^ (0.1 * (Lw0 – Di')) + 10^ (0.1 * Lw)]

  Lw being the self noise (acoustic power of flow noise in dB ref 1E-12W)

  The insertion loss taking into account the self noise (**Di** in dB) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

  Di = Lw0 – Lw1

  In case of rectangular ducts, the obtained results are comparable with the standardized measurement: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units- Insertion loss, flow noise and total pressure loss (2004).

6.3: How to use SILDIS

Operating conditions / security level / safety

See corresponding § in the chapter **General considerations**

For safety reasons, some cells of the original file provided to the user (as mentioned in the table below) for which input data are foreseen to be entered by the user are pre-filled with the value "1/0", among the yellow cells for which the color orange is used (*).

Worksheet	Cells
[in COALA]	E13, J37, W38

* something like that

** attention has to be paid to the fact that the considered sheet is not included in the worksheets listed below

Worksheets

Regarding the COmputation of BENDs, the software SILDIS is configurated in order to allow the user to access to various worksheets being linked as shown in fig. 6.2 (the overview of the worksheets being shown in table below).

[in-out COBEND]

Fig. 6.2

Note: temperature and pressure conditions as well as reference spectrum one should enter in worksheet in COALA

Worksheet	Suitable for mountings	Input data	Results
[in COALA]	all	for sets, for reference spectrum	--
[in-out COBEND]	COmputation of BENDs	for bend: dimensions, flow rate	indicators of performance (acoustics)

Input data, alerts and results: the key points

The best use of the software requires the knowledge of some key points in relation with:

- the **input data**

  See corresponding § in the chapter **General considerations**
- some **alerts** in case of input data involving a warning of the user
- the place where (and the way) some **results** are presented

Those key points are reviewed worksheet per worksheet hereafter: the cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out COBEND]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
mass flow rate Qm (kg/s)	I5	Input a real	
model of cut-off frequency fco	N5	Select a model (in the proposed list)	
model of 90° bend (type)	S5	Select a model (in the proposed list)	
adimensional bend radius	X5	Input a positive real	
model of self noise	AC5	Select a model (in the proposed list)	

Only in case of rectangular inlet cross section & rectangular outlet cross section

Item	Cell for input	Foreseen action	Comment
biggest dimension a1 (m)	H23	Input a positive real	
smallest dimension b1 (m	H24	Input a positive real	
biggest dimension a2 (m)	P23	Input a positive real	
smallest dimension b2 (m)	P24	Input a positive real	

Only in case of circular cross section

Item	Cell for input	Foreseen action	Comment
diameter D (m)	P47	Input a positive real	

Only in case of rectangular inlet cross section & circular outlet cross section

Item	Cell for input	Foreseen action	Comment
biggest dimension a1 (m)	H23	Input a positive real	
smallest dimension b1 (m)	H24	Input a positive real	
diameter D (m)	P47	Input a positive real	

- ***Main displays of the results :***

Tables of results in case of rectangular inlet cross section & rectangular outlet cross section

- **insertion loss without self noise Di'**: see lines 21 to 24 (columns S to AD)
- **self noise Lw**: see lines 26 to 30 (columns S to AD)
- **sound power level downstream of bend**: see lines 32 to 36 (columns S to AD)
- **insertion loss with self noise Di**: see lines 38 to 41 (columns S to AD)

Tables of results in case of circular cross section

- **insertion loss without self noise Di'**: see lines 44 to 47 (columns S to AD)
- **self noise Lw**: see lines 49 to 53 (columns S to AD)
- **sound power level downstream of bend**: see lines 55 to 59 (columns S to AD)
- **insertion loss with self noise Di**: see lines 61 to 64 (columns S to AD)

Tables of results in case of rectangular inlet cross section & circular outlet cross section

- **insertion loss without self noise Di'**: see lines 67 to 70 (columns S to AD)
- **self noise Lw**: see lines 72 to 76 (columns S to AD)
- **sound power level downstream of bend**: see lines 78 to 82 (columns S to AD)
- **insertion loss with self noise Di**: see lines 84 to 87 (columns S to AD)

6.4: Examples of computation with SILDIS

Example 6.4.1 circular bend

Envisaged application

It is wished to compute the acoustic performance of a circular bend for room conditions: temperature 17°C [1], pressure 1E5 Pa [2]. The sound power spectrum upstream of bend is as shown in the table below [3].

F(Hz)	63	125	250	500	1000	2000	4000	8000
Lw0 (dB ref 1pW)	73.3	60.6	45.0	41.1	37.0	34.7	37.4	32.5

The flow rate is 1400 m3/h [4]. Model of cut-off frequency fco not accounting flow speed is selected [5]. Bend radius is considered [6], adimensional bending ratio being 0.15 [7]. Regarding models of computation: the procedures basing the model referred to as 2081 are selected [8]. The duct is with a diameter D=250mm [9].

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).

The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Screenshots of the worksheets (for the example of computation)

Worksheet [in COALA]

Item	Cell for input	Foreseen action	Input	See placemark / comment
Temperature	D6	Input a real number	17	[1]
Pressure	D7	Input a real positive number	100000	[2]
Reference acoustic power spectrum	D65 to K65	Input numbers	73.3 ; 60.6 ; 45.0 ; 41.1 ; 37.0 ; 34.7 ; 37.4 ; 32.5	[3]

Worksheet [in-out COBEND]

- *Input data :*

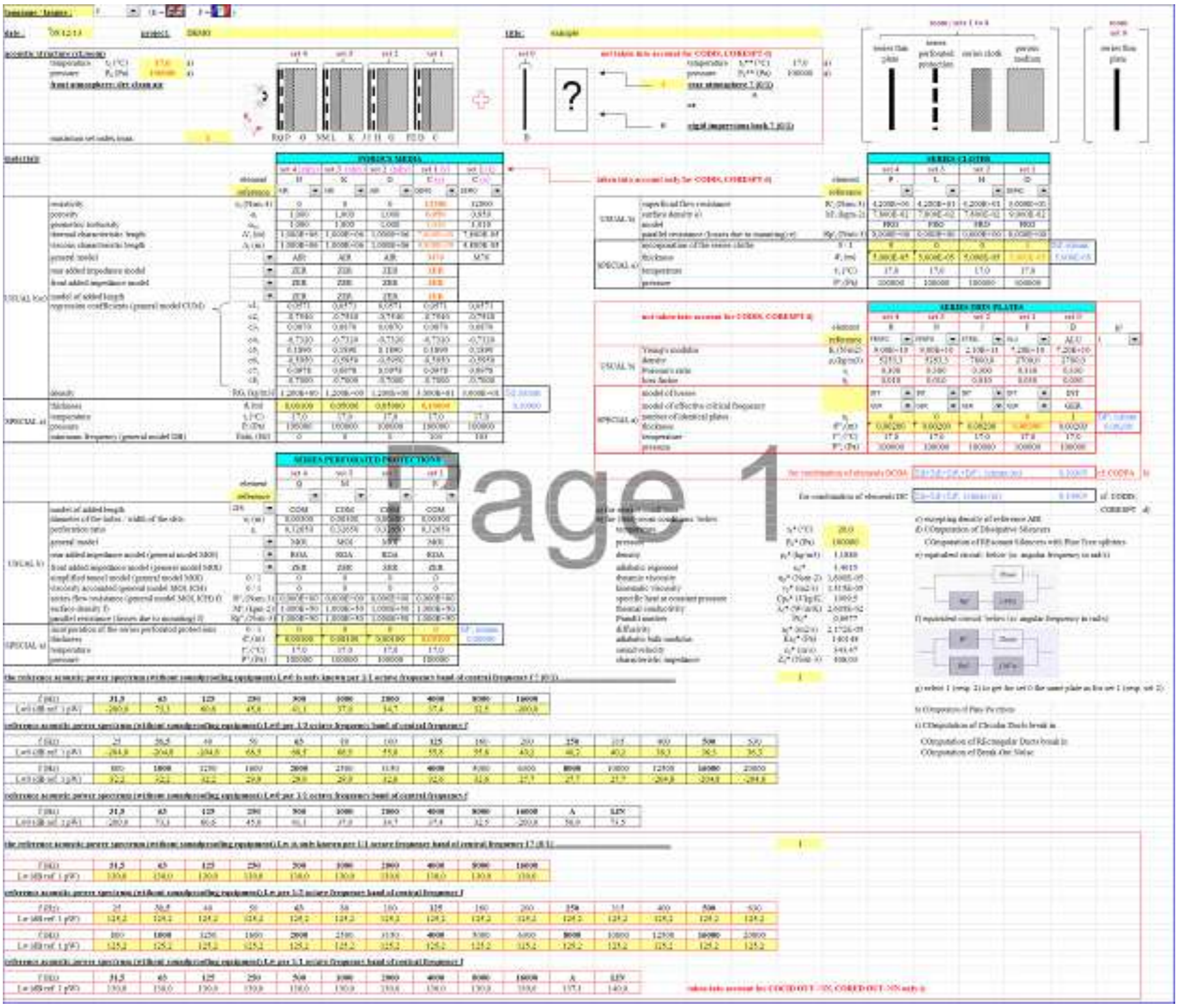
Item	Cell for input	Foreseen action	Input	See placemark / comment
mass flow rate Qm (kg/s)	I5	Input a real	=1400/3600*I10	[4]
model of cut-off frequency fco	N5	Select a model (in the proposed list)	HAN	[5]
model of 90° bend (type)	S5	Select a model (in the proposed list)	BE-RA	[6]
adimensional bend radius	X5	Input a positive real	0.15	[7]
model of self noise	AC5	Select a model (in the proposed list)	2081	[8]

Only in case of circular cross section

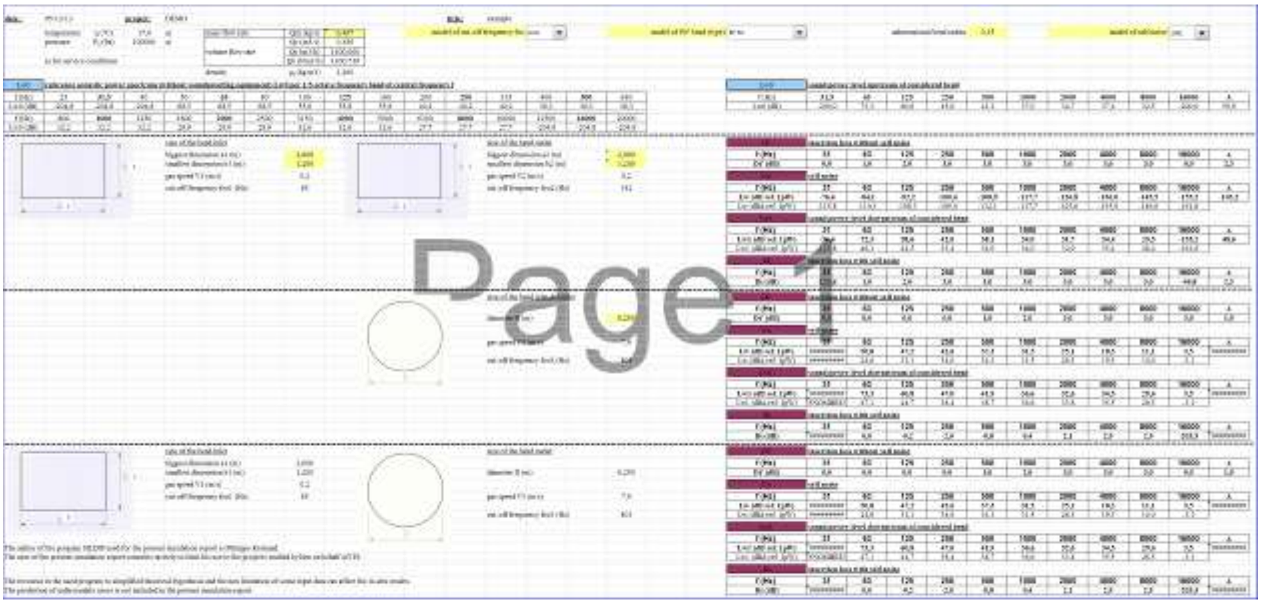
Item	Cell for input	Foreseen action	Input	See placemark / comment
diameter D (m)	P47	Input a positive real	0.25	[9]

Screenshots of the worksheets (for the example of computation)

Screenshot of worksheet [in-out COALA]



Screenshot of worksheet [in-out COBEND]



Appendix to Section 6: list of symbols

General

Cf. corresponding § in Section 1,2,3,4,5

Bend

Lw0: sound power level without soundproofing equipment (dB ref. 1pW) i.e. in the entrance plane of the bend
Lw1: sound power level with soundproofing equipment (dB ref. 1pW) i.e. in the exit plane of the bend

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Section 7: computation of nozzle reflection (MODULE 7 of the software)

7.1: Introduction

Terms and definitions

For the needs of the present user's manual, the following terms and definition apply:

No particular term or definition

Mountings and geometry

The geometry used for the computation of bends is as follows: rectangular or circular

7.2: Scientific and technical background

The prediction of acoustic performances of bends with SILDIS is founded on a scientific and technical background in relation with:

- analytical models for taking into account the properties of materials and various physical phenomena useful on the occasion of the computation
- measurement results for feeding some of those models and for allowing the necessary improvement (through correction factors) of the correlation between some calculations and on site observations

The obtained results are not comparable with standardized measurement due to the lack of such documents.

7.2.1Thermodynamics and fluid dynamics:

- **Steps of the computation**

Step [a]

All computations have been gathered in this single step for the sake of simplicity. See corresponding § in Section 1

7.2.2 Acoustics:

- **Bloc diagram** on fig 7.1 below

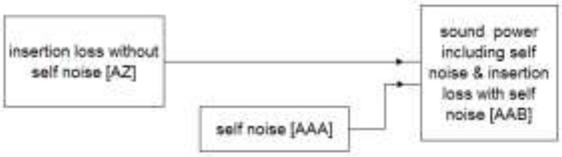


Fig. 7.1

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRxx-015x]

Note 2: the main steps (the steps involving a physical modeling) being referred to from [AW] to [AY] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

- **Steps of the computation**

Step [AZ]

This step aims at calculating the **insertion loss without self noise**

- ***Bibliography (references) :***

[AZ1]	
[AZ2]	

- ***Comments :***

    - the **insertion loss** is computed according to various models as shown in the table below:

model	**2081**	ISO
source	[AZ1]	[AZ2]

Step [AAA]

This step aims at calculating the **self noise**

- ***Bibliography (references) :***

No particular bibliography applicable

- ***Comments :***

    - the **self noise** is assumed to be negligible:

Step [AAB]

This step aims at calculating the **insertion loss including self noise**.

- ***Bibliography (references) :***

[AAB1] -	

- ***Comments :***

The sound power level including self noise (**Lw1** in dB ref 1E-12W) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

Lw1 = 10 * log [10^ (0.1 * (Lw0 – Di')) + 10^ (0.1 * Lw)]

Lw being the self noise (acoustic power of flow noise in dB ref 1E-12W)

The insertion loss taking into account the self noise (**Di** in dB) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

Di = Lw0 – Lw1

In case of rectangular ducts, the obtained results are comparable with the standardized measurement: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units- Insertion loss, flow noise and total pressure loss (2004).

7.3: How to use SILDIS

Operating conditions / security level / safety

See corresponding § in the chapter **General considerations**

For safety reasons, some cells of the original file provided to the user (as mentioned in the table below) for which input data are foreseen to be entered by the user are pre-filled with the value "1/0", among the yellow cells for which the color orange is used (*).

Worksheet	Cells
[in COALA]	E13, J37, W38

* something like that

** attention has to be paid to the fact that the considered sheet is not included in the worksheets listed below

Worksheets

Regarding the COmputation of NOZzle reflections, the software SILDIS is configurated in order to allow the user to access to various worksheets being linked as shown in fig. 7.2 (the overview of the worksheets being shown in table below).

[in-out CONOZ]

Fig. 7.2

Note: temperature and pressure conditions as well as reference spectrum one should enter in worksheet in COALA

Worksheet	Suitable for mountings	Input data	Results
[in COALA]	all	for sets, for reference spectrum	--
[in-out CONOZ]	COmputation of NOZzle reflection	dimensions	indicators of performance (acoustics)

Input data, alerts and results: the key points

The best use of the software requires the knowledge of some key points in relation with:

- the **input data**

  See corresponding § in the chapter **General considerations**
- some **alerts** in case of input data involving a warning of the user
- the place where (and the way) some **results** are presented

Those key points are reviewed worksheet per worksheet hereafter: the cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out CONOZ]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
mass flow rate Qm (kg/s)	I5	Input a real	
model of cut-off frequency fco	P5	Select a model (in the proposed list)	
model of reflection loss	V5	Select a model (in the proposed list)	
Solid angle factor	P7	Input a positive real	

Only in case of rectangular cross section

Item	Cell for input	Foreseen action	Comment
biggest dimension a (m)	P23	Input a positive real	
smallest dimension b (m	P24	Input a positive real	

Only in case of circular cross section

Item	Cell for input	Foreseen action	Comment
diameter D (m)	P47	Input a positive real	

- ***Main displays of the results :***

  Tables of results in case of rectangular inlet cross section & rectangular outlet cross section

  - **insertion loss without self noise Di'**: see lines 21 to 24 (columns S to AD)
  - **self noise Lw**: see lines 26 to 30 (columns S to AD)
  - **sound power level downtream**: see lines 32 to 36 (columns S to AD)
  - **insertion loss with self noise Di**: see lines 38 to 41 (columns S to AD)

  Tables of results in case of circular cross section

  - **insertion loss without self noise Di'**: see lines 44 to 47 (columns S to AD)

- **self noise Lw**: see lines 49 to 53 (columns S to AD)
- **sound power level downstream**: see lines 55 to 59 (columns S to AD)
- **insertion loss with self noise Di**: see lines 61 to 64 (columns S to AD)

7.4: Examples of computation with SILDIS

Example 7.4.1 circular mouth

Envisaged application

It is wished to compute the reflection loss of a circular mouth for room conditions: temperature 14.1°C [1], pressure 1E5 Pa [2] with the methodology corresponding to the so called model 2081 [3]. The considered solid angle factor is 2 [4]. The considered diameter of the mouth is 0.2 m [5].

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Screenshots of the worksheets (for the example of computation)

Worksheet [in COALA]

Item	Cell for input	Foreseen action	Input	See placemark / comment
Temperature	D6	Input a real number	14.1	[1]
Pressure	D7	Input a real positive number	100000	[2]

Worksheet [in-out CONOZ]

- ***Input data :***

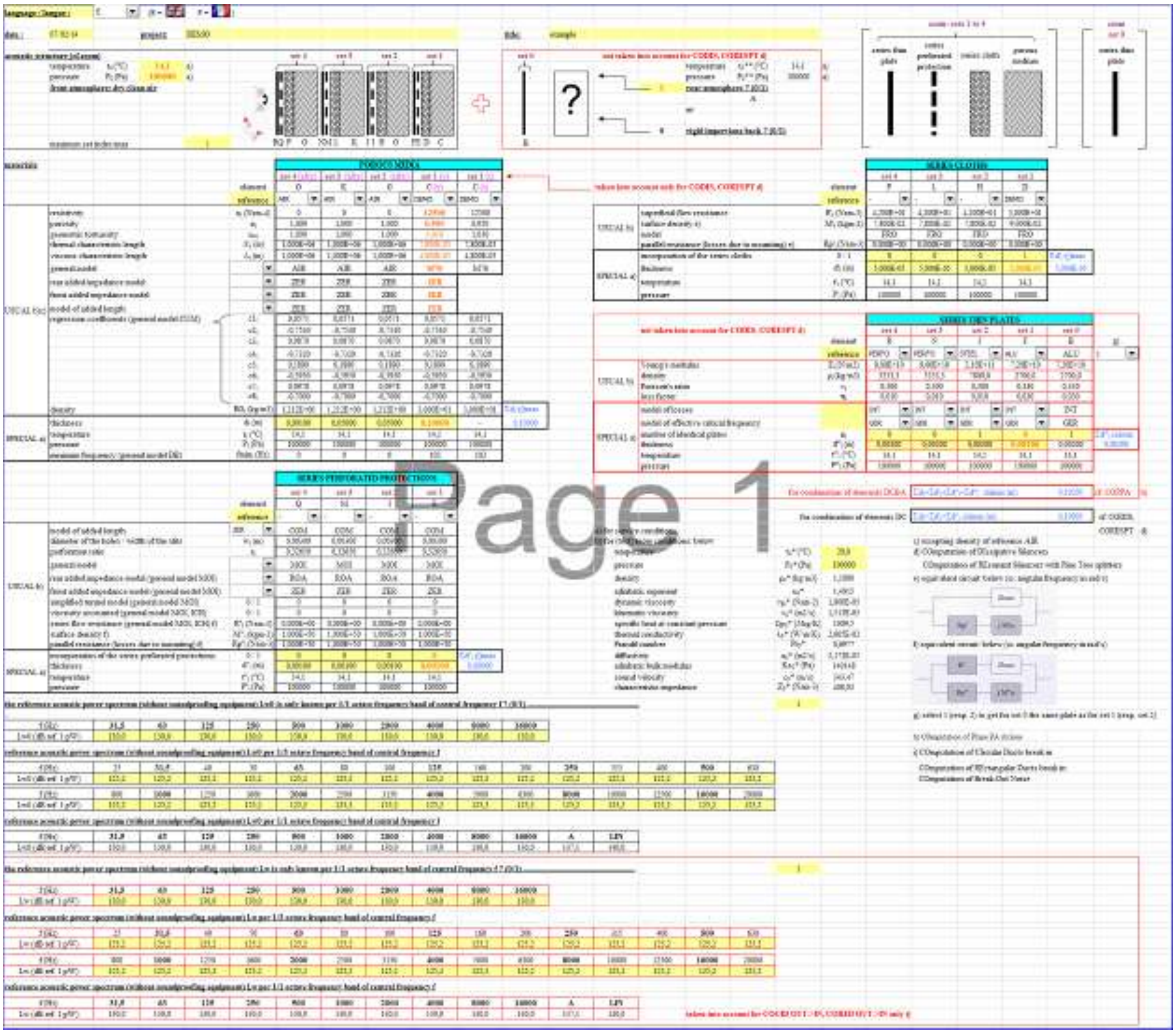
Item	Cell for input	Foreseen action	Input	See placemark / comment
mass flow rate Qm (kg/s)	I5	Input a real	-	
model of cut-off frequency fco	P5	Select a model (in the proposed list)	-	
model of reflection loss	V5	Select a model (in the proposed list)	2081	[3]
Solid angle factor	P7	Input a positive real	2	[4]

Only in case of circular cross section

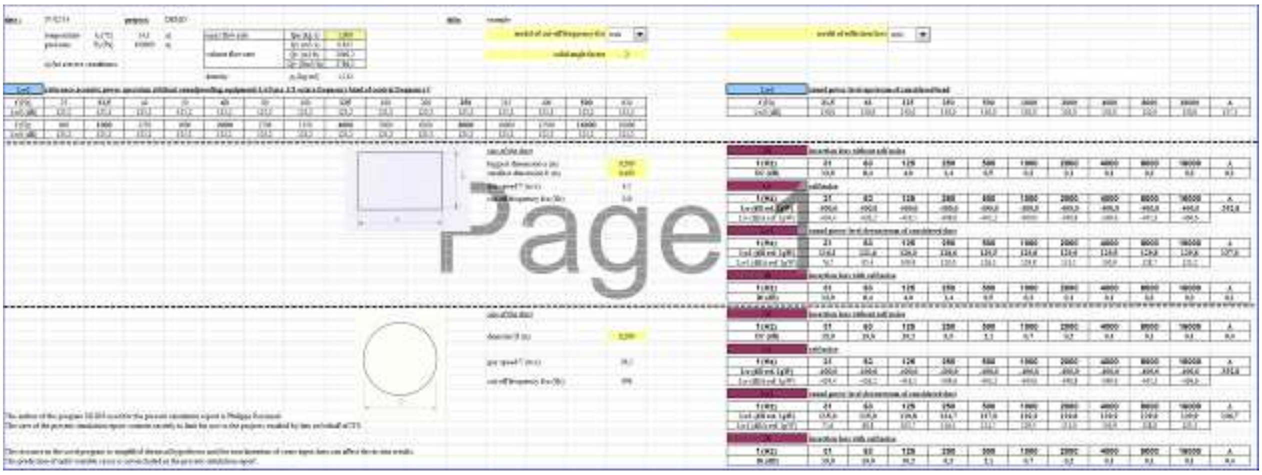
Item	Cell for input	Foreseen action	Input	See placemark / comment
diameter D (m)	P47	Input a positive real	0.2	[5]

<u>Screenshots of the worksheets (for the example of computation)</u>

Screenshot of worksheet [in-out COALA]



Screenshot of worksheet [in-out CONOZ]



Appendix to Section 7: list of symbols

General

Cf. corresponding § in Section 1,2,3,4,5, 6

Mouth

Lw0: sound power level without soundproofing equipment (dB ref. 1pW) i.e. in the entrance plane of the bend
Lw1: sound power level with soundproofing equipment (dB ref. 1pW) i.e. in the exit plane of the bend

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Section 8: computation of sound impact of a duct system (MODULE 8 of the software)

8.1: Introduction

Terms and definitions

For the needs of the present user’s manual, the following terms and definition apply:

No particular term or definition (cf. section 1, section 2, cf. section 3, cf. section 4, cf. section 5, cf. section 6)

Mountings and geometry

The geometry used for the computation of impact of a duct system is as follows (for each component):

inlet cross section	outlet cross section
rectangular	rectangular
circular	circular
rectangular	circular

8.2: Scientific and technical background

The prediction of sound impact of a duct system with SILDIS is founded on a scientific and technical background in relation with:

- analytical models for taking into account the properties of materials and various physical phenomena useful on the occasion of the computation
- measurement results for feeding some of those models and for allowing the necessary improvement (through correction factors) of the correlation between some calculations and on site observations

The obtained results are not comparable with standardized measurement due to the lack of such documents.

8.2.1Thermodynamics and fluid dynamics:

- **Steps of the computation**

Step [a]

All computations have been gathered in this single step for the sake of simplicity. See corresponding § in Section 1

8.2.2 Acoustics regarding the longitudinal noise propagation i.e. for the computation of the sound power level downstream of the duct system:

- **Bloc diagram** on fig IDS.1 below (this bloc diagram is used within a waterfall computation for all the components of the system, referred to as C1 to C10)

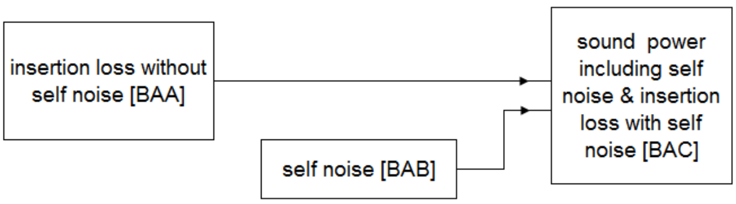
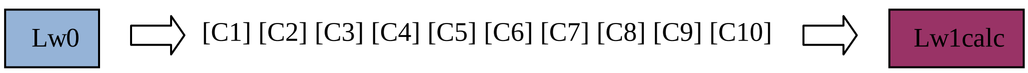


Fig. IDS.1



Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRxx-015x]

Note 2: the main steps (the steps involving a physical modeling) being referred to from [BAA] to [BAC] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

- **Steps of the computation**

Step [BAA]

This step aims at calculating the **sound power level downstream of the components** (resp. **downstream the full duct system**) as well as **insertion loss of each component including its self noise**.

- ***Bibliography (references) :***

[BAA1] -	

- ***Comments :***

The sound power level downstream of the component including self noise (**Lw1** in dB ref 1E-12W) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

Lw1 = 10 * log [10^ (0.1 * (Lw0 – Di’)) + 10^ (0.1 * Lw)]

Lw being the self noise (acoustic power of flow noise in dB ref 1E-12W)

The insertion loss taking into account the self noise (**Di** in dB) is basically computed at frequency steps of 1/1 octave (in reference to a reference acoustic power spectrum **Lw0** ref 1E-12W).

Di = Lw0 – Lw1

In case of rectangular ducts, the obtained results are comparable with the standardized measurement: see NF EN ISO 7235 Acoustics - Laboratory measurement procedures for ducted silencers and air terminal units- Insertion loss, flow noise and total pressure loss (2004).

Step [BAB]

This step aims at calculating the **sound pressure level downstream at the specified distance of the duct system**

- ***Bibliography (references) :***

[BAB1] -	

- ***Comments :***

The sound pressure level downstream of the full duct system at a specified distance (**Lp1calc** in dB ref 120µPa) is basically computed at frequency steps of 1/1 octave as

Lp1calc = Lw1calc + (Lp1calc - Lw1calc - DI) + DI

8.2.3 Acoustics regarding the transverse noise propagation i.e. for the computation of the sound power level transmitted by the walls of the duct system:

- **Bloc diagram** on fig IDS.2 below (the components of the system are referred to as C1 to C10)

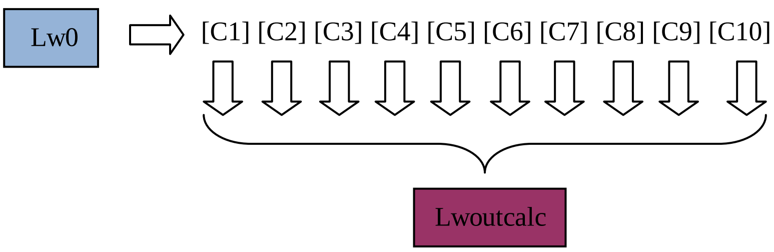


Fig. IDS.2

Note 1: the service conditions dependence has been omitted for the sake of simplicity. See: report [PhRxx-015x]

Note 2: the main steps (the steps involving a physical modeling) being referred to from [AAB] to [AAB] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

- **Steps of the computation**

Step [BAC]

This step aims at calculating the **sound pressure level at a specified distance of the duct system**

- ***Bibliography (references) :***

[BAC1] -	

- ***Comments :***

The sound pressure level downstream of the full duct system at a specified distance (**Lpoutcalc** in dB ref 120µPa) is basically computed at frequency steps of 1/1 octave as

Lpoutcalc = Lwoutcalc + (Lpoutcalc - Lwoutcalc)

8.3: How to use SILDIS

Operating conditions / security level / safety

See corresponding § in the chapter **General considerations**

For safety reasons, some cells of the original file provided to the user (as mentioned in the table below) for which input data are foreseen to be entered by the user are pre-filled with the value "1/0", among the yellow cells for which the color orange is used (*).

Worksheet	Cells
[in COALA]	E13, J37, W38

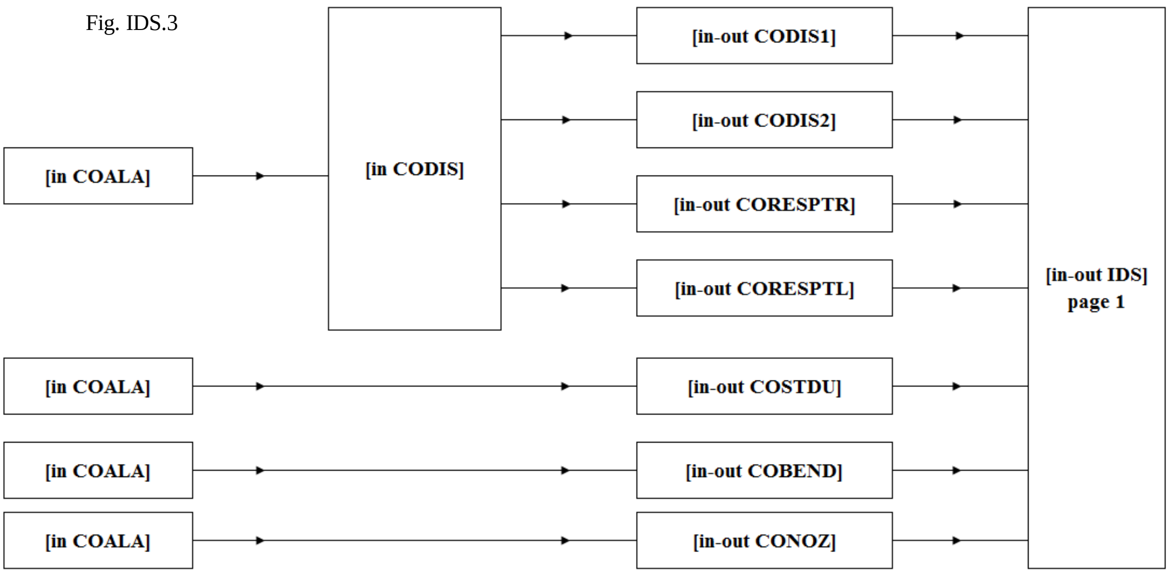
* something like that

** attention has to be paid to the fact that the considered sheet is not included in the worksheets listed below

Worksheets regarding the longitudinal noise propagation i.e. for the computation of the sound power level downstream of the duct system

Regarding the computation of the Impact of a Duct System, the software SILDIS is configurated in order to allow the user to access to various worksheets being linked as shown in fig. IDS.3 (the overview of the worksheets being shown in table below).

Fig. IDS.3



Note: temperature and pressure conditions as well as reference spectrum one should enter in worksheet in COALA

Worksheet	Suitable for mountings	Input data	Results
[in COALA]	all	for sets, for reference spectrum	--
[in CODIS]	all	particular conditions for the design of the silencer	--
[in-out CODIS1]	R, R'', C1, C2	condition of propagation (of sound)	indicators of performance (acoustics & Aerodynamics)
[in-out CODIS2	Q, C0		
[in-out CORESPTL]	RPTR, RPTR''		
[in-out CORESPTR]	RPTL, RPTL''		
[in-out COSTDU]	all	for duct: dimensions, flow rate	
[in-out COBEND]	all	for bend: dimensions, flow rate	indicators of performance (acoustics
[in-out CONOZ]	all	for duct: dimensions	indicators of performance (acoustics)

Input data, alerts and results: the key points

The best use of the software requires the knowledge of some key points in relation with:

- the **input data**

  See corresponding § in the chapter **General considerations**
- some **alerts** in case of input data involving a warning of the user
- the place where (and the way) some **results** are presented

Those key points are reviewed worksheet per worksheet hereafter: the cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out IDS] page 1

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Noise source	L3	Input a string	
Configuration	L5	Input a string	
GSA (*) type	L7	Input a string	* GSA = General Silencing Arrangement. Cf. appendix GSAC-EX
Component	C25 to C34	Input a string	
Matrix	D25 to D34	Select a model (in the proposed list)	
Lw1ref (dB ref. 1pW)	E88 to O88	Input a real	If no input in N88 (resp. O88), displayed value is computed from 1/1 octave bends input data
Directivity index (dB)	E95 to M95	Input a real	
Lp1calc-Lw1calc-DI (dB)	N97	Input a real	
Lp1ref (dB ref. 1pW)	E107 to O107	Input a real	If no input in N107 (resp. O107), displayed value is computed from 1/1 octave bends input data
Comments	C113 to C122	Input a string	

In case of use of models BYO17 to BYO19 only

Item	Cell for input	Foreseen action	Comment
Insertion loss without flow noise (dB)	E135 to M137	Input a real	Bring Your Own input data
Flow noise (dB)	E142 to M144	Input a real	Bring Your Own input data

- ***Main displays of the results :***

  Tables of results for components

  - **sound power level downstream of components Lw1**: see lines 50 to 62 (columns B to O)

- **insertion loss with self noise Di**: see lines 64 to 76 (columns B to O)

<u>Tables of results for full duct system</u>

- **sound power level downstream of duct system Lw1calc**: see lines 78 to 82 (columns B to O)
- **sound pressure level downstream of duct system Lp1calc at a specified distance**: see lines 97 to 101 (columns B to O)

<u>Worksheets regarding the transverse noise propagation i.e. for the computation of the sound power level transmitted by the walls of the duct system</u>

Regarding the computation of IMPACT, the software SILDIS is configurated in order to allow the user to access to various worksheets being linked as shown in fig. IDS.4 (the overview of the worksheets being shown in table below).

Fig. IDS.4

Note: temperature and pressure conditions as well as reference spectrum one should enter in worksheet in COALA

Worksheet	Suitable for mountings	Input data	Results
[in COALA]	all	for sets, for reference spectrum	--
[in COBON]	all	for dimensions, for models of computation	--

<u>Input data, alerts and results: the key points</u>

The best use of the software requires the knowledge of some key points in relation with:

- the **<u>input data</u>**

  See corresponding § in the chapter **General considerations**
- some **<u>alerts</u>** in case of input data involving a warning of the user
- the place where (and the way) some **<u>results</u>** are presented

Those key points are reviewed worksheet per worksheet hereafter: the cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out IDS] page 1

- ***<u>Input data :</u>***

Item	Cell for input	Foreseen action	Comment
Sound power level radiated by components walls	U17 to AC26	Enter a real	
Lwoutref (dB ref. 1pW)	U38 to AE38	Input a real	If no input in AD38 (resp. AE38), displayed value is computed from 1/1 octave bends input data
Lpoutcalc - Lwoutcalc (dB)	U45 to U54	Input a real	
Lpoutref (dB ref. 20µPa)	U88 to AE88	Input a real	If no input in AD88 (resp. AE88), displayed value is computed from 1/1 octave bends input data
Comments	T113 to T122	Input a string	

- ***<u>Main displays of the results :</u>***

<u>Tables of results for components</u>

- **sound pressure level at a specified distance Lpoutcalc**: see lines 56 to 68 (columns S to AE)

<u>Tables of results for full duct system</u>

- **sound power level radiated by components walls Lwoutcalc**: see lines 28 to 32 (columns S to AE)

8.4: Examples of computation with SILDIS

Example 8.4.1 cylindrical attenuator without core + bend + (straight) duct , the acoustic performance of each component being predetermined

Envisaged application

It is wished to compute for room (temperature 17°C [1], pressure 1E5 Pa [2]) the acoustic performance of a duct system made of:

- **a cylindrical attenuator without core**

The insertion loss without flow noise Di' is as shown in the table below [3].

F(Hz)	63	125	250	500	1000	2000	4000	8000
Di'(dB)	2	4	8	16	31	22	12	11

The flow noise Lw is assumed to be negligible [4].

Note: the performance of this silencer may have been simulated with SILDIS. If so, performance would be displayed in worksheet referred to as [in-out CODIS2]

- **a bend**

The insertion loss without flow noise Di' is as shown in the table below [5].

F(Hz)	63	125	250	500	1000	2000	4000	8000
Di'(dB)	0	0	0	1	2	3	3	3

The flow noise Lw is as shown in the table below [6]

F(Hz)	63	125	250	500	1000	2000	4000	8000
Lw (dB ref.1pW)	26.9	23.0	18.1	12.5	6.5	-0.1	-7.0	-14.4

Note: the performance of this bend may have been simulated with SILDIS. If so, performance would be displayed in worksheet referred to as [in-out COBEND]

- **a (straight) duct**

The insertion loss without flow noise Di' is as shown in the table below [7].

F(Hz)	63	125	250	500	1000	2000	4000	8000
Di'(dB)	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.3

The flow noise Lw is assumed to be negligible [8].

Note: the performance of this duct may have been simulated with SILDIS. If so, performance would be displayed in worksheet referred to as [in-out COBEND]

The sound power spectrum upstream of the duct system is as shown in the table below [9].

F(Hz)	63	125	250	500	1000	2000	4000	8000
Lw0 (dB ref 1pW)	64.7	51.1	38.6	31.5	26.1	20.4	22.9	24.9

The acoustic performance of each component is predetermined and referred to as BYO17 [10], BYO18 [11], BYO19 [12]

Input data

The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in COALA]

Item	Cell for input	Foreseen action	Input	See placemark / comment
Temperature	D6	Input a real number	17	[1]
Pressure	D7	Input a real positive number	100000	[2]
Reference acoustic power spectrum	D65 to K65	Input numbers	64.7 ; 51.1 ; 38.6 ; 31.5 26.1 ; 20.4 ; 22.9 ; 24.9	[9]

Worksheet [in-out IDS] page 1

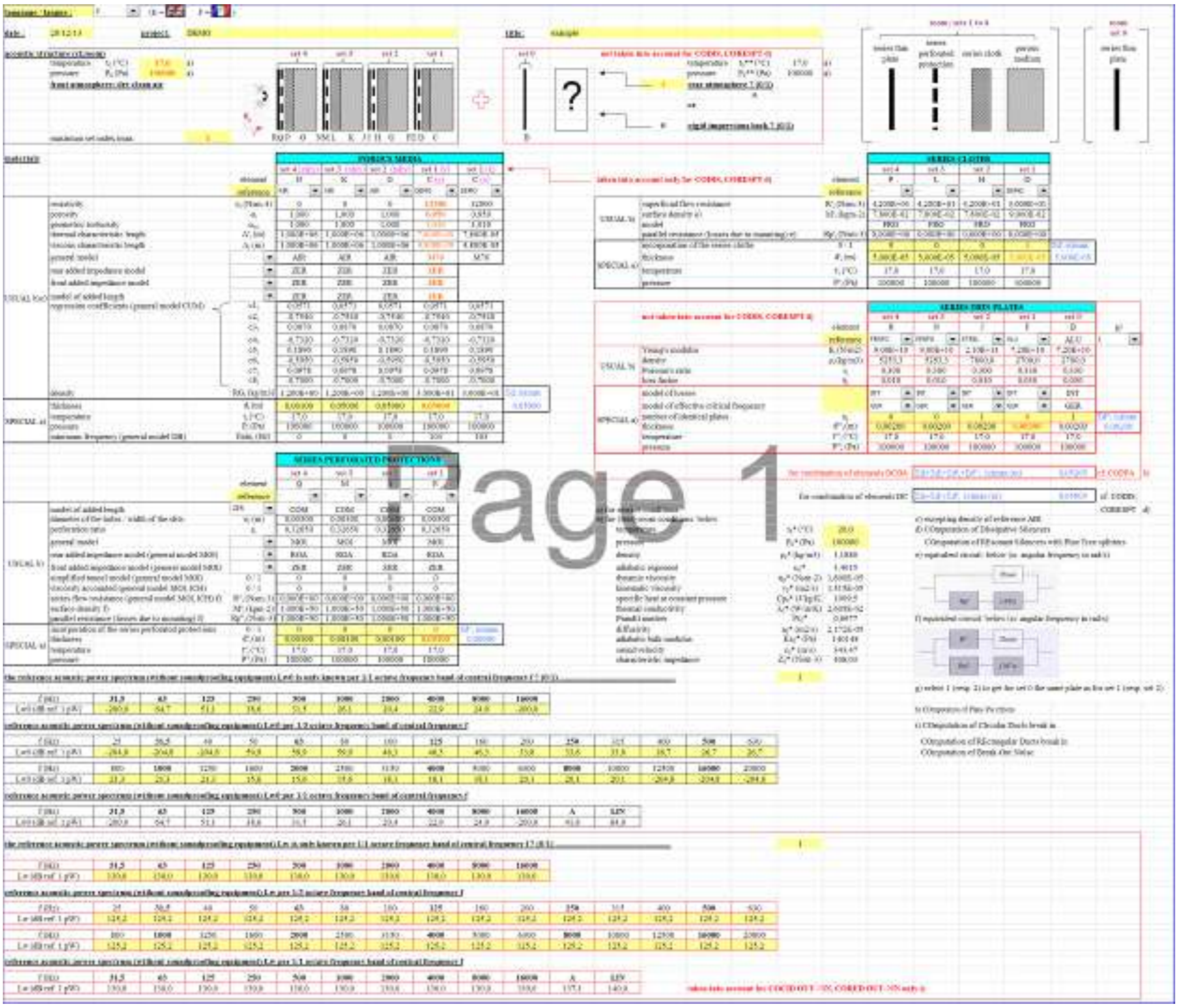
Item	Cell for input	Foreseen action	Input	See placemark / comment
Noise source	L3	Input a string	-	
Configuration	L5	Input a string	-	
GSA (*) type	L7	Input a string	-	
Component	C25 to C27	Input a string	cylindrical attenuator without core resp. bend resp. (straight) duct	
Matrix	D25 to D27	Select a model (in the proposed list)	BYO17 resp. BYO18 resp. BYO19	[10],[11],[12] if not predetermined, but computed with SILDIS, the selection should have been CODIS2 resp. COBEND resp. COSTDU
Lw1ref (dB ref. 1pW)	E88 to O88	Input a real	-	
Directivity index (dB)	E95 to M95	Input a real	-	
Lp1calc-Lw1calc-DI (dB)	N97	Input a real	-	
Lp1ref (dB ref. 1pW)	E107 to O107	Input a real	-	
Comments	C113 to C122	Input a string	-	

In case of use of models BYO17 to BYO19 only

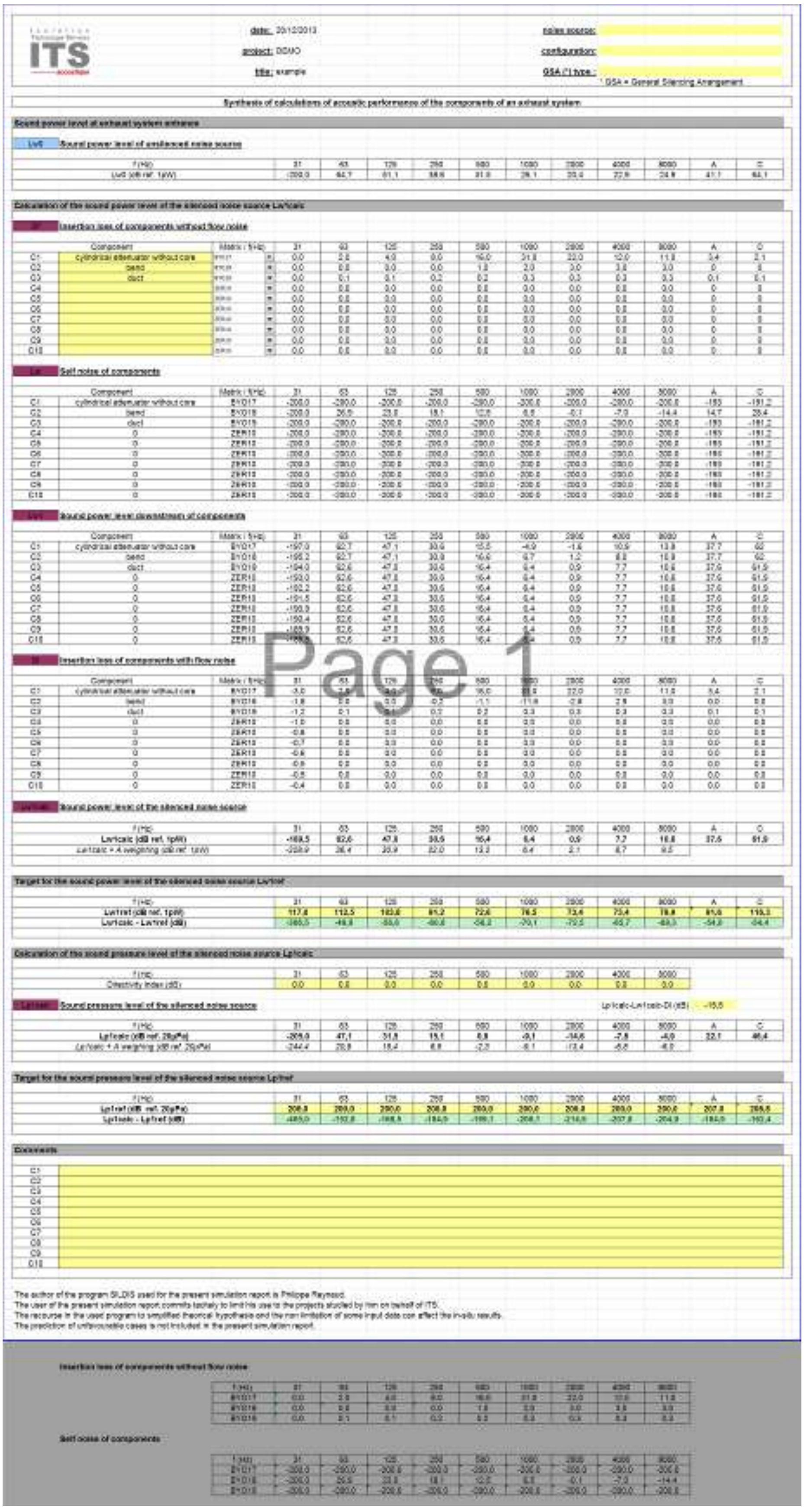
Item	Cell for input	Foreseen action	Input	See placemark / comment
Insertion loss without flow noise (dB)	E135 to M137	Input a real	2 ; 4 ; 8 ; 16 ; 31 ; 22 ; 12 ; 11 resp. 0 ; 0 ; 0 ; 1 ; 2 ; 3 ; 3 ;3 resp.0.1 ; 0.1 ; 0.2 ; 0.2 ; 0.3 ; 0.3 ; 0.3 ; 0.3	[3] resp. [5] resp. [7]
Flow noise (dB)	E142 to M144	Input a real	-200 ; -200 ; -200 ; -200 ; -200 ; -200 ; -200 ; -200 resp. 26.9 ; 23.0 ; 18.1 ; 12.5 ; 6.5 ; -0.1 ; -7.0 ; -14.4 resp. -200 ; -200 ; -200 ; -200 ; -200 ; -200 ; -200 ; -200	[4] resp. [6] resp. [8]

Screenshots of the worksheets (for the example of computation)

Worksheet [in COALA]



Worksheet [in-out IDS] page 1



Appendix to Section 8: list of symbols

General

Cf. corresponding § in Section 1,2,3,4

Duct system

Lp1calc: sound pressure level with soundproofing equipment downstream of the duct system (dB ref. 1pW) i.e. at a specified distance from the exit plane of the duct system: calculated with SILDIS
Lp1ref: sound pressure level with soundproofing equipment downstream of the duct system (dB ref. 1pW) i.e. at a specified distance from the exit plane of the duct system: reference = target, imposed limit, etc…

Lw0: sound power level without soundproofing equipment (dB ref. 1pW) i.e. in the entrance plane of the component
Lw1: sound power level with soundproofing equipment (dB ref. 1pW) i.e. in the exit plane of the component
Lw1calc: sound power level with soundproofing equipment downstream of the duct system (dB ref. 1pW) i.e. in the exit plane of the duct system: calculated with SILDIS
Lw1ref: sound power level with soundproofing equipment downstream of the duct system (dB ref. 1pW) i.e. in the exit plane of the duct system: reference = target, imposed limit, etc…

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Section 9: computation of sound decay in enclosed spaces (MODULE 9 of the software)

9.1: Introduction

Terms and definitions

For the needs of the present user's manual, the following terms and definition apply (cf. NF EN ISO 3382-2):

Reverberation time (T): duration necessary for the average acoustic volumetric energy in a room to decrease by 60 dB after noise off. Reverberation time can be computed by using a dynamic range below 60 dB, and then extrapolating to the time corresponding to a 60 dB decay. It is then noted accordingly. Thus, if T is derived from the first instant where the decay curve reaches 5 dB and 25 dB below initial level, it is noted T20. If decay values from 5 dB to 35 dB below the initial level are used, it is noted T30.

Geometry

In case of a rectangular (shoebox shaped) room, the geometry is as follows (this is not the only geometry for which simulation can be performed):

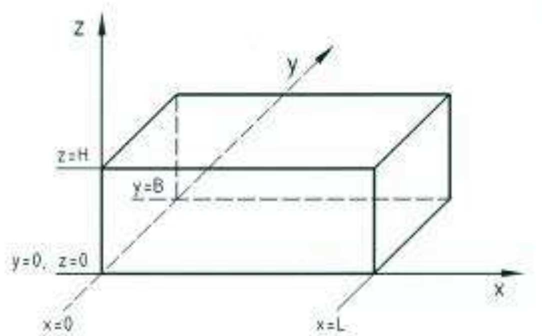


fig.9.1

9.2: Scientific and technical background

The prediction of sound decay in a room with SILDIS is founded on a scientific and technical background in relation with:

- analytical models for taking into account the various physical phenomena useful on the occasion of the computation
- measurement results for feeding some of those models and for allowing the necessary improvement (through correction factors) of the correlation between some calculations and on site observations

As far as reverberation time is concerned, the obtained results are comparable with the standardized measurement: see NF EN ISO 3382-2 Acoustics - Measurement of room acoustics parameters- Part 2: reverberation time in ordinary rooms.

9.2.1Thermodynamics and fluid dynamics:

- **Steps of the computation**

Step [a]

All computations have been gathered in this single step for the sake of simplicity. See corresponding § in Section 1

9.2.2 Acoustics:

- **Bloc diagram :**

The computation scheme of sound decay in a room is according the bloc-diagram below (cf. fig. 9.2):

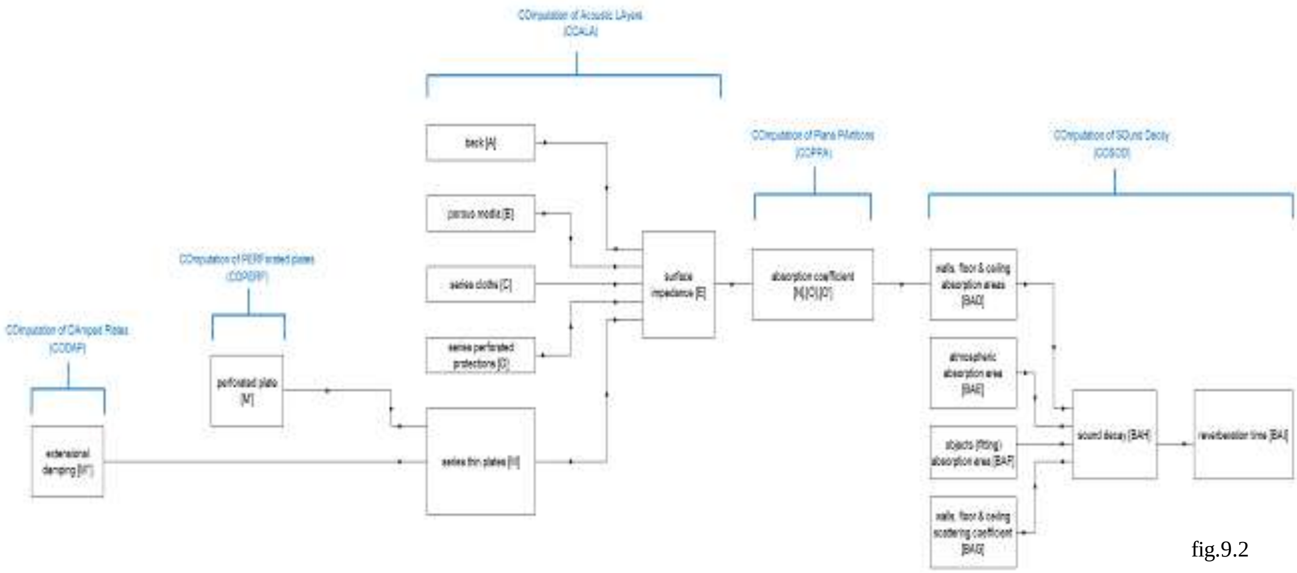


fig.9.2

Note 1: the service conditions dependence has been omitted for the sake of simplicity.

Note 2: the main steps (the steps involving a physical modeling) being referred to from [BAD] to [BAI] have been taken into account for the bloc-diagram above (some of the parameters of the above bloc diagram are not independent); the frequency dependence has been omitted for the sake of simplicity

Note 3: depending on the model selected for the step [BAH], steps [BAE], [BAF], [BAG] may not be part of the computation scheme

Note 4: depending on the model selected for the step [BAI], step [BAH] may not be a separate part of the computation scheme (when the used approach is based on explicit reverberation time allowing a direct calculation of reverberation time)

- **Steps of the computation**

Step [a]

Cf. section 1

Steps [N], [O]

Cf. section 2

Step [BAD]

This step aims at calculating the **walls, floor & ceiling absorption area**

- ***Bibliography (references) :***

[BAD1]	
[BAD2]	

- ***Comments :***

  - the **absorption coefficients alpha** of walls, floor and ceiling are accounted as shown in the table below:

model	NAT	MOD
source	[BAD1]	[BAD2]
Comment	NATural (i.e. as entered as Sabine's coefficients)	MODified absorption coefficients in order to limit them to 100 %):

Step [BAE]

This step aims at accounting **atmospheric absorption**

- ***Bibliography (references) :***

[BAE1] -	

- ***Comments :***
  - the **atmospheric absorption area** is computed using an attenuation coefficient of sound power in air accounted for climatic conditions as shown in the table below:

Temperature (°C)	Humidity ratio (%)
10	30-50
	50-70
	70-90
20	30-50
	50-70
	70-90

Step [BAF]

This step aims at accounting **objects (fitting) absorption area**

- ***Bibliography (references) :***

[BAF1] -	
[BAF2] -	

Step [BAG]

This step aims at accounting the **scattering coefficient of walls, floor & ceiling**

- ***Bibliography (references) :***

[BAG1] -	
[BAG2] -	
[BAG3] -	
[BAG4] -	

Step [BAH]

This step aims at calculating the **sound decay** in the room (after noise off)

- ***Bibliography (references) :***

[BAH1] -	
[BAH2] -	
[BAH3] -	
[BAH4] -	

Step [BAI]

This step aims at calculating the **reverberation time** of the room

- ***Bibliography (references) :***

[BAI1] - -	
[BAI2] -	
[BAI3] -	
[BAI4]	
[BAI5] -	
[BAI6] -	
[BAI7] -	
[BAI8] -	
[BAI9] -	
[BAI10] -	
[BAI11] -	
[BAI12] - -	
[BAI13] -	
[BAI14] -	
[BAI15] -	
[BAI16] -	
[BAI17] -	

- ***Comments when accounting (natural) Sabine's coefficients):***

  - the **reverberation time T** is computed according to various general models as shown in the table below (with the exception of model SAK, all models are implemented in considering - in parallel - on the one hand: original formulas and on the other hand modified formulas to account solid angles)

Model	SAB
Source	[BAI1]
Applicable even for non-rectangular room	yes
Non-diffuse sound fields accounted (*)	no
Scattering accounted	no
Explicit formula for T	yes
Comment	(**)

* as per [BAI6], when one suppose a diffuse acoustic field, this means that the dimensions of enclosed space are similar and that absorption is distributed in the whole space; the existence of diffusing objects is moderating those limitations.

- ***Comments when accounting modified absorption coefficients in order to limit them to 100 %:***

  - the **reverberation time T** is computed according to various general models as shown in the table below (with the exception of model SAK, all models are implemented in considering - in parallel - on the one hand: original formulas and on the other hand modified formulas to account solid angles)

Model	SAB	EYR	MIL	CRE	KUT		
Source	[BAI1]	[BAI1]	[BAI1]	[BAI2] equation 2-31	[BAI2][BAI3][BAI4]][BAI5]		
Applicable even for non-rectangular room	yes	yes	yes	yes	yes	yes	yes
Non-diffuse sound fields accounted (*)	no	no	no	no	no (**)(***)	no (**)(***)	no (**)(***)
Scattering accounted	no	no	no	no	no	no	no
Explicit formula for T	yes	yes	yes	yes	yes	yes	yes
Comment	-	-	-	-	Correction for inhomogeneity accounting differences in absorption coefficient of elementary surfaces αk (k=1to N)	Correction for inhomogeneity accounting differences in absorption coefficient of opposite walls αxj, αyj ,αzj (j=1 to 2)	Correction for inhomogeneity accounting differences in absorption coefficient of opposite walls couples αx, αy, αx

Model	FIT	NEU	ARA		
Source	[BAI1]	[BAI6] to [BAI9]	[BAI10	[BAI10]	[BAI10]
Applicable even for non-rectangular room	no	no	no	no	no
Non-diffuse sound fields accounted (*)	no	no	no	no	no
Scattering accounted	no	no	no	no	no
Explicit formula for T	yes	yes	yes	yes	yes
Comment	-	-	(****)	(****)	(****)

Model	ISO			NIJ	SAK	HOD
Source	[BAI11] to [BAI12]	[BAI11] to [BAI12]	[BAI11] to [BAI12]	[BAI13]	[BAI14] to [BAI16]	[BAI17]
Applicable even for non-rectangular room	no	no	no	yes	no	no
Non-diffuse sound fields accounted (*)	yes	yes	yes	no	yes	no
Scattering accounted	yes	yes	yes	no	yes	no
Explicit formula for T	yes if appropriate model used	yes if appropriate model used	no if appropriate model used	yes	no	yes
Comment	-	-	-	-	-	-

* as per [BAI11], when one suppose a diffuse acoustic field, this means that the dimensions of enclosed space are similar and that absorption is distributed in the whole space; the existence of diffusing objects is moderating those limitations.

** for the model KUT only, the **relative variance of the path length distribution** γ^2 (depending on room dimensions ratio) is accounted according to various models as shown in the table below:

Model	ZER	PAR	TOT
Source	-	[BAI3] equation 13	[BAI3] equation 12
Comment	γ^2 =ZERo	PARtial (power series approximation)	TOTal (exact formula)

*** for the model KUT only, the **inhomogeneity (non-uniform placement) of sound absorption** is accounted according to various models as shown in the table below:

Model	ZER	PAR1	PAR2	TOT
Source	-	[BAI3] equation 27	[BAI2] equation 2-80	[BAI3] equation 25
Comment	ZERo consideration	PARtial (power series approximation & **not** accounting Σρi2Si2)	**not** accounting Σρi2Si2)	TOTal (exact formula)

**** for the model ARA only, un-cleared variations occur for modelling when accounting solid angles

The obtained results are comparable with standardized measurement: cf. NF EN ISO 3382-2 Acoustics - Measurement of room acoustics parameters- Part 2: reverberation time in ordinary rooms.

9.3: How to use SILDIS

Operating conditions / security level / safety

See corresponding § in the chapter **General considerations**

For safety reasons, some cells of the original file provided to the user (as mentioned in the table below) for which input data are foreseen to be entered by the user are pre-filled with the value "1/0", among the yellow cells for which the color orange is used (*).

Worksheet	Cells
[in COALA]	E13, J37
[in-out COPPA]	X53, X54

* something like that

Worksheets

Regarding the COmputation of SOund Decay, the software SILDIS is configurated in order to allow the user to access to 1 worksheet referred to as "in-out COSOD" being possibly linked as shown in fig. 9.3 to worksheets considered in previous sections of this User's Manuel (the overview of the worksheets being shown in table below).

[in-out COALA] → [in-out COPPA] → [in-out COSOD]

Fig. 9.3

Worksheet	Suitable for mountings	Input data	Results
[in COALA]	all	material parameters	--
[in COPPA]	all	limit angle of computation	absorption coefficient
[in-out COSOD]	all	absorption coefficient, areas of absorbing surfaces, models accounted	reverberation time

Input data, alerts and results: the key points

The best use of the software requires the knowledge of some key points in relation with:

- the **input data**

  See corresponding § in the chapter **General considerations**

  As far as porous media, series cloths and series perforated protections are concerned, specific data bases (libraries) (will) allow the design to be made with in-built engineering data (constants) referred to as "Usual" in the worksheets of the software. Warning: some properties of the presently referenced materials still not have been checked by reliable sources. See also report [PhRXX-015] Collection of soundproofing constructions systems: a companion to "User's manual for the software SILDIS"

  - **data base (library) for porous media**
    - ✓ contents of the library: **21 possible references of material layers**
  - **data base (library) for series cloths**
    - ✓ contents of the library: **21 possible references of material layers**

    Note: the cloth referenced RESISTAIR can be used (with an appropriate value for the flow resistance) for the simulation of losses of a thin plate (for example at normal incidence: due to the conditions of mounting)
  - **data base (library) for series perforated protections**
    - ✓ contents of the library: **21 possible references of material layers**
- some **alerts** in case of input data involving a warning of the user
- the place where (and the way) some **results** are presented

Those key points are reviewed worksheet per worksheet hereafter: the cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out COSOD]

- ***Input data :***

Item	Cell for input	Foreseen action	Comment
Language	C1	for English input E, for French input F	
Date	H1	Modification of the displayed date	
Project	B3	Input a string	
Title	B4	Input a string	
Temperature	I5	Input a real number	
Length L (m)	D7	Input a real number	Room dimension according x-axis
Width B (m)	D8	Input a real number	Room dimension according y-axis
Height H (m)	D9	Input a real number	Room dimension according z-axis
xs	I12	Input a real number	Solid angle calculation point coordinate according x-axis
ys	I13	Input a real number	Solid angle calculation point coordinate according y-axis
zs	I14	Input a real number	Solid angle calculation point coordinate according z-axis
hs	I16	Input a real number	Source height
Room form variance γ^2	E19	Input a real number	For model KUT only
Objet fraction ψ	E21	Input a real number	For model ISO only
Sound poser level reference spectrum (dB ref.1 pW)	E24 to M24	Input a real number	
Sound attenuation in air coefficient	E29 to M29	Input a real number	In 1E-3 Neper per meter
Area of elementary surfaces	E35 to E39 & E45 to E49 [resp. E62 to E66 &, E72 to E76 ; E89 to E93 & E99 to E103]	Input a real number	
Absorption coefficient	E35 to M39 & E45 to M49 [resp. E62 to M66 &, E72 to M76 ; E89 to M93 & E99 to M103]	Input a real number	Sabine's coefficient for partitions couples x, y & z
Scattering coefficient δ	E42 to M42 & E52 to M52 [resp. E69 to M69 &, E79 to M79 ; E96 to M96 & E106 to M106]	Input a real number	
Equivalent absorption area of objects associated with surfaces	E55 to M55 [resp. E82 to M82 ; E109 to M109]	Input a real number	
Equivalent absorption area of objects present in central area	E115 to M115	Input a real number	
Consideration of model MOD for limitation to 100 % of absorption coefficients	K128	For NO input 0, for YES input 1	If NO is entered, Sabine's coefficient will be used for the simulation

(0/1)			
Variance model	C132	Select a model	For general model KUT only
Inhomogeneity model	C134	Select a model	For general model KUT only
Modified formula (0/1)	G132	For NO input 0, for YES input 1	For general model NIJ only
atmospheric attenuation in each direction (0/1)	K134		For general model ARA only
Elementary time period Δt (s) for calculation of T	O132	Input a real number	For general models ISO & SAK only
T evaluation range start (dB)	O133	Input a real number ≤ 0	For general models ISO & SAK only
T evaluation range end (dB)	O134	Input a real number < 0	For general models ISO & SAK only

- ***Comments*** :
  - data of the second table (below) are taken into account only for the calculations using solid angles

Item	Cell for input	Foreseen action	Comment
y mini, y maxi, z mini, z maxi	R35 to U39 & R45 to U49	Input a real number	Coordinates of elementary surfaces in x planes i.e. in planes x= 0 & x=L
x mini, x maxi, z mini, z maxi	R62 to U66 &, R72 to U76	Input a real number	Coordinates of elementary surfaces in y planes i.e. in planes y= 0 & y=B
x mini, x maxi, y mini, y maxi	R89 to U93 & R99 to U103	Input a real number	Coordinates of elementary surfaces in z planes i.e. in planes z= 0 & z=H

- ***Main displays of the results :***

  Tables of results

  - **reverberation time considering absorption coefficients as entered, potentially above 100%** : see lines 117 to 126
    - ✓ **not considering atmospheric attenuation, not considering objects** see lines 119 to 121 : **not accounting solid angles** (columns A to O), **accounting solid angles** (columns R to AB)
    - ✓ **considering atmospheric attenuation, not considering objects** see lines 124 to 127 : **not accounting solid angles** (columns A to O), **accounting solid angles** (columns R to AB)

  - **reverberation time considering eventually modified absorption coefficients** : see lines 136 to 208
    - ✓ **not considering atmospheric attenuation, not considering objects** see lines 136 to 156 : **not accounting solid angles** (columns A to O), **accounting solid angles** (columns R to AB)
    - ✓ **considering atmospheric attenuation, not considering objects** see lines 161 to 181: **not accounting solid angles** (columns A to O), **accounting solid angles** (columns R to AB)
    - ✓ **considering atmospheric attenuation, considering objects** see lines 186 to 206 : **not accounting solid angles** (columns A to O), **accounting solid angles** (columns R to AB)

9.4: Examples of computation with SILDIS

Example 9.4.1 room with discrepancies in dimensions & with non-homogene distribution of absorbing areas

Envisaged application

It is wished to compute for a temperature 14.8°C [1] the reverberation time of an empty room with dimensions L=20 m [2], B=10m [3], H=5m [4], when neglecting atmospheric absorption [5], with absorption coefficients as follows: short walls 0.10 [6], long walls 0.20 [7], floor & ceiling 0.40 [8] and with a scattering coefficient of 0.20 [9] for all surfaces. For models ISO and SAK, , elementary time period Δt (s) to be considered is 0.005 s [10], T30 to be considered [11].

Input data

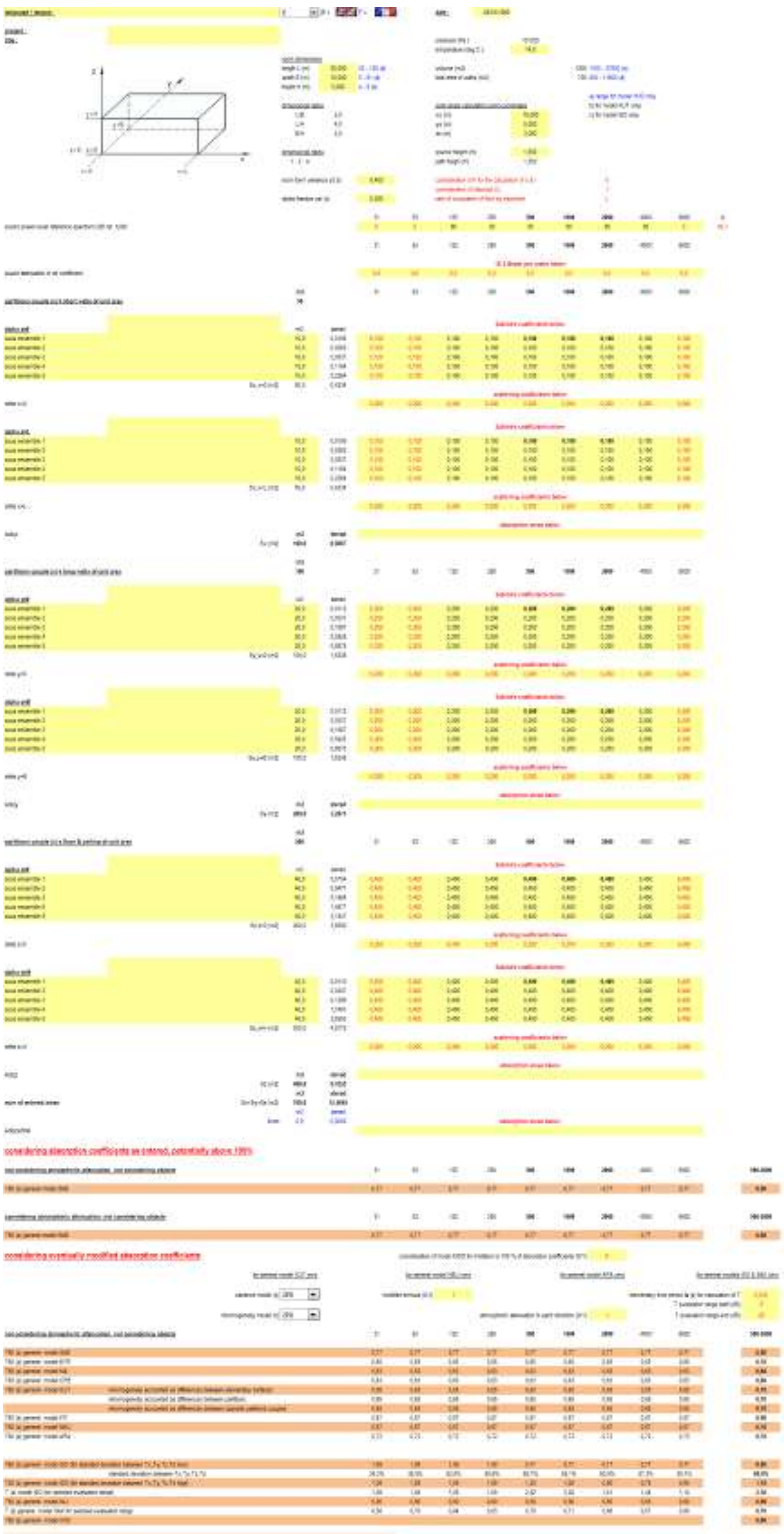
The input data required for the computation are listed hereafter in reference with the above data (see placemarks).
The input cells will be referred to thanks to their EXCEL's coordinates (column / line) in the following part of the present user's manual.

Worksheet [in-out COSOD]

Item	Cell for input	Foreseen action	Input	See placemark / comment
Temperature	I5	Input a real number	14.8	[1]
Length L (m)	D7	Input a real number	20	[2]
Width B (m)	D8	Input a real number	10	[3]
Height H (m)	D9	Input a real number	5	[4]
Sound attenuation in air coefficient	E29 to M29	Input a real number	0	[5]
Area of elementary surfaces	E35 to E39 & E45 to E49 [resp. E62 to E66 &, E72 to E76 ; E89 to E93 & E99 to E103]	Input a real number	10	-
Absorption coefficient	E35 to M39 & E45 to M49	Input a real number	0.10	[6]
Absorption coefficient	E62 to M66 &, E72 to M76	Input a real number	0.20	[7]
Absorption coefficient	E89 to M93 & E99 to M103	Input a real number	0.40	[8]
Scattering coefficient δ	E42 to M42 & E52 to M52 [resp. E69 to M69 &, E79 to M79 ; E96 to M96 & E106 to M106]	Input a real number	0.20	[9]
Elementary time period Δt (s) for calculation of T	O132	Input a real number	0.005	[10]
T evaluation range start (dB)	O133	Input a real number **≤ 0**	-5	[11]
T evaluation range end (dB)	O134	Input a real number **< 0**	-35	[11]

Screenshots of the worksheets (for the example of computation)

Worksheet [in-out COSOD]



Appendix to Section 9: list of symbols

General

Cf. corresponding § in Sections 1 & 2

Sound decay

A obj, x (m2) : equivalent absorption area of objects associated with surfaces for x=0 and x=L
A obj, y (m2) : equivalent absorption area of objects associated with surfaces for y=0 and y=B
A obj, z (m2) : equivalent absorption area of objects associated with surfaces for z=0 and z=H

N: number of elementary absorbing surfaces considered (for walls, floor & ceiling)
T: reverberation time (s)
T20: reverberation time derived from the first instant where the decay curve reaches 5 dB and 25 dB below initial level (s)
T30: reverberation time derived from the first instant where the decay curve reaches 5 dB and 35 dB below initial level (s)

αx: average absorption coefficient of the couple of opposite walls in direction x
αy: average absorption coefficient of the couple of opposite walls in direction y
αz: average absorption coefficient of the couple of opposite walls in direction z

αx1 (resp. αx2): average absorption coefficient of 1 among the couple of opposite walls in direction x
αy1 (resp. αy2): average absorption coefficient of 1 among the couple of opposite walls in direction y
αz1 (resp. αz2): average absorption coefficient of 1 among the couple of opposite walls in direction z

αk: absorption coefficient of an elementary wall, floor or ceiling surface considered among N

δ x=0 [resp. δ x=L] : scattering coefficient of surface x=0 [resp. x=L]
δ y=0 [resp. δ y=B] : scattering coefficient of surface y=0 [resp. y=B]
δ z=0 [resp. δ z=H] : scattering coefficient of surface z=0 [resp. z=H]